

SHAKE AND SNIFF
The secret signals in a handshake

NewScientist

WEEKLY March 7 - 13, 2015

LARGER HARDER COLLIDER

Forget the Higgs.
Now we're searching
for the root of reality

YOUR BRAIN ON MIGRAINE

Rethinking the world's most misunderstood neurological disorder

DAMBUSTERS

The end of Brazil's
hydroelectric dreams

GATEWAY TO ADDICTION

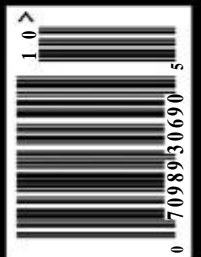
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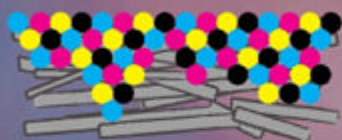


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ENRICO SACCHETTI

Double or nothing

Will the revamped LHC make or break physics?

NATURE has proven remarkably accommodating to particle physicists over the past century. Take the photon, devised by Einstein in 1905 as a theoretical convenience to help explain electromagnetism and light. Nature obliged, and the photon turned out to be real. A quarter-century later, Paul Dirac conjured up antimatter. It soon turned up in cosmic rays.

And so to 2012, when jubilant physicists at CERN's Large Hadron Collider, near Geneva in Switzerland, announced that they had found the Higgs boson pretty much where they expected it.

The discovery of the Higgs put the finishing touch to the standard model of particle physics. Barring a few small wrinkles, everything this theory predicted has now been confirmed experimentally. But completion of the model still leaves a lot for physics to explain, with no clear indication of where to go next.

With the LHC powering up again after a two-year refit, for the first time there is no consensus on what it should find (see page 30). If the theoreticians keep their run of success going, it should turn up the first decent evidence for supersymmetry, the next-generation theory that could explain dark matter, gravity and

other phenomena not covered by the standard model. But then, if you believe the theories, the LHC should already have seen many such indications. It hasn't.

That leaves theorists and experimentalists alike in a state of excitement and trepidation. The rebooted LHC could demonstrate that supersymmetry is on the right track, albeit not quite as we expected. It could find a clutch of new particles that point in a surprising direction. Or it could find nothing. Either of the first

"It would be a real sadness if the LHC discovers nothing, because then the subject I love would come to an end"

two scenarios would be exciting. The last looms ominously.

"It would be a real sadness if the LHC discovers nothing, because then the subject I love would come to an end. But if that's the way the universe is, that's the way it is," David Tong, professor of theoretical physics at the University of Cambridge, told the audience last month at a *New Scientist* event in London. If the upgraded LHC isn't powerful enough to make progress, the days of smashing protons together to reveal the fundamental nature of reality

are probably over. We could not be confident of finding anything new until we reached vastly greater energies – too great for any collider conceivable today.

But there are alternatives.

Some argue that messy collisions between protons are not the ideal way to find physics beyond the standard model. Plans already exist for more precise electron colliders – from the International Linear Collider, which might be built in Japan, to a circular collider at CERN up to 100 kilometres long – far bigger than the LHC.

Our quest to understand the nature of reality thus stands at a crossroads. Past success has bred confidence in the Big Physics approach. Government agencies, emboldened by the excitement of discovery and the emergence of spin-offs like the World Wide Web, have been happy to spend billions of dollars on particle experiments. But if the LHC comes up with nothing, will the confidence still be there to fund the next generation of machines?

Many physicists would claim that their success over the years owes more to judgement than luck. Now, without the steady hand of agreed theory to guide the way, they may need all the luck they can get. ■

Syrian war's dry roots

THE consequences of leaving on your lights might be worse than you think. A drought exacerbated by climate change might have contributed to the outbreak of civil war in Syria.

Colin Kelley of the University of California, Santa Barbara, and his colleagues analysed Syrian weather data since 1931, and found that the winter rainfall that is crucial for crops has steadily declined. Over the same period, temperatures have risen, drying soils faster. The only explanation lies in humanity's greenhouse emissions, says Kelley. Climate models, his team found, predict such changes for the region.

The team used statistics to tease apart annual ups and downs in precipitation from the long-term drying that seems to be linked to

climbing carbon dioxide emissions (*PNAS*, doi.org/2jw).

Those natural yearly variations led to the occasional drought, but the long-term drying exacerbated the 2007-2010 drought, making it the most severe in the observed record, says Kelley. The drought and an inadequate response to it led to crop failure, a rise in crop prices and mass migration into slums with few job opportunities. Affected cities included Homs and Hama, where protests began in 2011.

"Placing stress on a society tends to make violence more likely," says Andrew Solow of the Woods Hole Oceanographic Institution in Massachusetts. But, he says, political unrest in the Middle East might have led to violence in Syria anyway.



Caused by climate change?

UNITED NATIONS RELIEF AND WORKS AGENCY/VIAGETTY IMAGES

Dwarf world Dawn

CROSS dwarf planets off the bucket list. As *New Scientist* went to press, NASA's Dawn spacecraft was on track to arrive at Ceres, which will become the first dwarf planet to get a spacecraft visitor, early on 6 March. The icy world may hold clues as to how our solar system came together.

Dawn previously orbited the asteroid Vesta, and took off in 2012 to chase Ceres, a 950-kilometre-wide object in the asteroid belt. The arrival will

planet for a year. During this time, the craft will gather information about Ceres's unique features, particularly subsurface geological processes, in an effort to learn more about it and about the role that similar objects had in the formation of the solar system.

The mission will also provide a closer look at a strange sight in one of Ceres's craters: two bright spots, recently imaged by Dawn on its approach. The spots have puzzled NASA scientists, who believe they may be ice or salts, or perhaps related to the faint plumes of water vapour detected by the European Space Agency's Herschel spacecraft early last year. Although Dawn's instruments are not designed to confirm the vapour finding, they may be able to observe it indirectly.

"The mystery will be solved, but it's one that's really got us on the edge of our seats," said Carol Raymond, Dawn's deputy principal investigator, at a press conference on Monday.

The more famous dwarf planet Pluto will have to wait for its time in the spotlight: the New Horizons spacecraft will arrive there in July.

Flu, man flu or cold?

ATISHOO! Chances are that if you're 30 or over, it's just a cold.

That's the message from work showing that people aged 30 or over can expect just two bouts of flu per decade. Children are likely to succumb every other year. This may be because adults have better immunity or mix less with others, says Steven Riley of Imperial College London. His team screened blood samples from people in southern China for antibodies to seasonal flu strains that circulated

globally between 1968 and 2009. An algorithm then worked out in which years each person had become ill (*PLoS Biology*, DOI: 10.1371/journal.pbio.100208).

But things could change. The World Health Organization has warned of a rising number of avian flu strains emerging over the past two years. "This appears to be happening now at an accelerated pace," it said. The worry is that the strains could infect humans: "The consequences for human health are unpredictable yet potentially ominous," it concluded.

"The arrival will set a personal record for Dawn, making it the first to visit two different worlds"

set a personal record for Dawn, making it the first spacecraft to visit two different worlds.

The spacecraft should swing into orbit around Ceres at 4.20 am Pacific time, but NASA scientists won't be able to confirm success until the afternoon, when the spacecraft will be in the right spot to send signals back to mission control. Dawn will orbit the dwarf

World's most infectious dress

AN INEXPENSIVE dress worn to a wedding in Scotland turned out to be a highly contagious virus.

A Tumblr user uploaded a picture of the dress, saying she was having an argument about what colour it was: white and gold or blue and black. BuzzFeed republished it and it broke the site's record for visitors to a web page. Practically every media outlet and dozens of commercial enterprises rushed to piggyback on the phenomenon, and

on Friday there was even less sense to be had out of the internet than normal. Blogger and viral-content expert Neetzan Zimmerman tweeted that it was the "viral singularity".

As for the dress itself, cognitive scientist Erin Goddard at Macquarie University in Sydney, Australia, told *New Scientist* the confusion over its colour came about because people were unconsciously correcting for the colour they assumed the source of light on the dress to be.

Freedom on the net

YOU don't often see dancing in the streets of the US capital. But last week, campaigners for "net neutrality" apparently did so, after the Federal Communication Commission (FCC) voted in

"I think the nearly 4 million people who wrote in to the FCC is the most significant piece of the equation"

favour of rules to classify internet service as a utility.

The new regulation, which will apply to US broadband providers, is seen as crucial to ensure that all information is treated equally in transmission – so-called net neutrality. This has been described as a human rights issue.

Victor Pickard of the University of Pennsylvania says widespread public engagement in the issue was instrumental to the outcome: "I think the nearly 4 million people who wrote in to the FCC is certainly the most significant piece of the equation."

But a Republican-led FCC of the future could overturn the decision, adds Pickard. Indeed, the current rules are already expected to be challenged in court. "I feel many people are declaring victory," he says, "and once you have the public tuning out that's when the damage could occur. You might see some pushback against these regulations."



You too can own this meme



PAULO PEREIRA/GREENPEACE

Now you see it, now you don't

Deforestation rise

TIMBER! Deforestation in the Amazon has skyrocketed in the past six months.

That's according to an analysis of satellite images issued by Brazil's non-profit research institute, IMAZON. It compared monthly deforestation figures with the same month a year before. The difference ranged from a 136 per cent increase in August to a 467 per cent rise in October.

"If this trend continues, it won't be long before the world's tropical forests are essentially gone"

"Rates have way more than doubled over the equivalent period in the previous year," says Phillip Fearnside, an ecologist with Brazil's Amazon research agency INPA. And the study probably underestimates the problem, because the satellite used can only recognise clearings larger than 250,000 square metres. Many farm plots are smaller.

The figures come as a surprise given that deforestation in the Brazilian Amazon declined by 77 per cent between 2004 and 2011 (PNAS, doi.org/wbn).

Brazil's Amazon isn't an isolated case, though. A study released last week shows that the loss of tropical forests around the globe

between the 1990s and 2010 accelerated by 62 per cent (*Geophysical Research Letters*, doi.org/2h7). "The rate of deforestation is way up," says the lead author of last week's study, Do-Hyung Kim at the University of Maryland. "If this trend continues, it won't be long before the world's tropical forests are essentially gone."

For more on the Amazon, see page 34

Hitch a ride

CALLING all galactic hitchhikers: the European Space Agency is offering a ride. In 2020, ESA plans to launch a spacecraft to an asteroid, and will have room for up to six mini-spacecraft called CubeSats onboard.

These 10-centimetre-wide vessels are cheap to build, but no CubeSat has ever flown beyond Earth's orbit, so it could be a chance to grab a slice of history.

ESA is inviting applications from research teams and companies across Europe. Although even hobbyist teams can build CubeSats, James DiCorcia of Deep Space Industries, a firm that is also working on a CubeSat mother ship, thinks ESA will be looking for experienced launchers. But even simple spacecraft will come in handy. "At this early stage in asteroid-proximity operations, almost any data acquired is useful," he says.

60 SECONDS

Europe's hard line on GM

Preventing farmers from growing genetically modified crops just got a lot easier in the European Union. Member states previously had to justify proposed bans with scientific evidence of potential harm to health or the environment. But now, rules passed on Monday mean bans can be invoked for a host of other reasons.

Swiss ice breaker

Switzerland officially submitted its post-2020 climate action plan to the UN this week, making it the first country to do so ahead of the international climate summit in Paris in December. It plans to reduce its greenhouse gas emissions to between 70 and 85 per cent below 1990 levels by 2050.

Kew Gardens cropped

The UK government must urgently give the Royal Botanic Gardens at Kew in London more financial freedom to protect its scientific research, after almost 50 scientists were made redundant there. The recommendation came in a report by the House of Commons Science and Technology Committee, published on Wednesday.

Orbital explosion

In space no one can hear you boom. A US military satellite has exploded after 20 years in orbit. The DMSP-F13 satellite was launched in 1995 to gather weather data for the air force and navy, but was no longer in full-time operation. Its power system overheated at some point in February, blowing it to smithereens.

Emotional popcorn

Trying to shed the pounds? Think twice about that tearjerker. Moviegoers across seven US cities who watched the sad film *Solaris* ate an average of 55 per cent more popcorn than those watching comedy *My Big Fat Greek Wedding*, say researchers from the Cornell University Food and Brand Lab (*JAMA Internal Medicine*, in press).

Yeast's heavenly potential

Genetically modified microbes could oust flowers in the making of perfume

Aviva Rutkin

SITTING before me is a vial of cloudy white broth. Biologist Patrick Boyle invites me to take a sniff. To my amateur nose, the liquid smells green and sweet, a little like fresh-cut grass, a little like a bunch of flowers.

The concoction is a microbial perfume. Cooked up in the laboratories of Ginkgo BioWorks in Boston, it contains yeast that has been genetically engineered to smell of roses. Its ultimate purpose: to become part of a

"We're at the mercy of nature with roses. Cultured products would give us a more consistent odour"

designer fragrance, one where its presence rivals the rose oils often used in luxury scents.

The "cultured rose" was born out of a marriage between Ginkgo – which bills itself as "the world's first organism engineering foundry" – and Robertet, a French flavours and fragrance company founded in 1850. Robertet prides itself on the natural ingredients it uses in perfumes created for clients such as Chloé and Bottega Veneta, as well as its scents for household products like detergents.

Rose oil is a classic perfume component. Traditionally, roses are grown in vast fields in Bulgaria or Turkey, then picked by hand and distilled to extract the aromatic oil. But from the fragrance companies' perspective, this approach is unreliable. Both the quality and the price of roses can fluctuate wildly from year to year, influenced by factors such as natural disasters, labour shortages, diseases or simply a poor growing season. "You have raw materials that will go from

\$10 to \$100 a kilo because there's a shortage or an embargo," says Bob Weinstein, chief operating officer at Robertet.

Perfumers can use a synthetic substitute, created by mixing four or five chemicals together to approximate natural rose scent. This can be convincing, but some perfumers say it falls short of the

rich subtleties that would distinguish a high-end fragrance.

Culturing microbes to produce scents is not only cheaper than using naturally sourced ingredients, but also gives perfumers more control over fragrances, says Ben Fundaro, director of perfumery at Robertet. "We're basically at the mercy of

nature with some of these crops," he says. "If we could produce in a more controlled environment, the odour would be more consistent."

The approach being pursued at Ginkgo starts with the DNA of the rose itself. In order to make the compounds responsible for their flowers' distinctive smell (see "On the scent of a rose", right),



ALEXA BRUNET/PICTURE TANK

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plants need to use enzymes, and the team must find the genes coding for these. Once that's done, Ginkgo can engineer a number of strains of yeast, each with a genome modified to ensure that the microbes' metabolic reactions result in one of the desired compounds. This might be accomplished by tweaking the genome or by adding genes from a rose or another plant, such as corn or hyacinth, that does the same job.

"Our goal is to recreate the rose biosynthetic pathways, even if we don't use rose genes to do it," says

Boyle. "We often find that a different but highly related gene from a different species works better in yeast than the rose gene that has the function we want."

Every month or so, Ginkgo sends samples of the strains to Robertet perfumers. They evaluate them and send critiques back to Ginkgo, asking for a scent to be made stronger or weaker, or to play up its floral, musky or fruity qualities. Once the strains for the individual components have been cleared by the perfumers, Ginkgo will produce a single strain of yeast that has all the genetic modifications – their attempt at the ideal rose scent.

The best rose oil, says Fundaro, smells fresh and clean, "very true to the way the rose would smell in the air if you were in a rose garden or next to a bouquet". One issue with the cultured rose fragrance is that it retains the yeast's characteristic sour smell. Before Boyle's team is done, they must find a way to downplay this odour, perhaps by moderating some of the genetic pathways that contribute to it, or by carefully filtering the final product.

Ginkgo isn't the only company to have anticipated manufacturers' desire for cultured fragrances and flavours. Californian company Amyris has partnered with Swiss firm Firmenich to work on lab-made patchouli oil. Allylix, another California company, cultures a version of vetiver oil, a woody extract of an Indian perennial grass.

"The basic material is sugar and microorganisms, so it's much more stable," says Toine Janssen, CEO of Isobionics, based in Geleen in the Netherlands. Isobionics relies on bacteria to make valencene, a compound found in oranges and often used in soft drinks. "It's like brewing beer. If you have lots of fermenters, you can make as much as you like."

Shota Atsumi, a chemist at the University of California, Davis, sees another potential upside to cultured products: they may

ON THE SCENT OF A ROSE

Why does a rose smell like a rose?

To uncover the secrets of a flower's scent, chemists use a technique called headspace analysis. They lock the plant in an airtight glass container, trapping the volatile components responsible for its smell. It's then easy to do tests to identify each compound and measure its concentration.

Headspace analyses have revealed hundreds of compounds among the different rose varieties. The most common contributors to the classic rose smell are:

Citronellol Also found in citronella candles. Imparts a sweet smell.

Geraniol Strengthens the rose scent.

Nerol Makes roses smell fresh.

Farnesol This sweet-smelling compound in combination with the three above give roses their characteristic smell.

Linalool Often used in cleaning products with floral fragrances.

Eugenol Also found in bay leaves and clove oil, it has a spicy smell.

Rose oxide Has a grassy smell; strengthens roses' initial fragrance, or top note.

replace some synthetic scents, the vast majority of which are produced from petrochemicals. Last year, in an effort to demonstrate the potential of cultured scents as a renewable alternative, Atsumi's research team altered the DNA of *E. coli* to make the bacteria smell like bananas and blueberries.

It's not clear what customers will make of a microorganism-cultured perfume. Victoria Frolova, a perfume industry analyst, says companies may choose not to highlight the unusual product process on the label. "For reasons of intellectual property, the fragrance industry

orchids that resist cultivation, for example. Another rare ingredient is ambergris, an earthy substance made inside a sperm whale's guts; people collect it whenever it washes up on the beach. These could one day be cultured by comparing the genomes of their animal and plant sources to ones already on tap in the lab.

Or fragrance companies could turn to bioengineers to order custom-grown versions of scents. This is the idea that excites Martin Gras, a perfumer for over 40 years. "Perfumers get inspired by nature," says Gras. "I can imagine with genetic engineering, you can make new odours just by changing the genes of the flower. It is another way of thinking."

The biologists at Ginkgo plan to push these boundaries. They are now seeking samples of Ice Age wildflowers that have been preserved in permafrost. If the surviving DNA fragments contain genes present in modern-day plants, researchers may be able to develop a yeast strain that mimics the extinct plants' long-lost fragrances.

"Can we recreate the scent of flowers that can't be grown because they don't exist any more?" asks Boyle. "People have sequenced Neanderthals, so it's not out of the question." Parfum Extinctio, the ultimate elite fragrance. ■

"Can we recreate an extinct flower's scent? We've sequenced Neanderthals, so it's not out of question"

doesn't share the components of perfume, much less how they are synthesised," she says. "How would anyone know that the molecules in their eau de toilette are yeast-produced?"

As researchers get better at producing cultured fragrances, they may become more adventurous, attempting to replicate much scarcer ingredients. Many natural fragrances prized by perfumers are extremely difficult to get hold of: compounds from jungle



Much easier to just leave it to prove

Climate-proofing Europe

Can €190 billion save Europe from the wrath of climate change?

Andy Coghlan

AS CHAOS from climate change ramps up in the coming decades, making floods, droughts and heatwaves commonplace, Europe will be ready. So says the European Environment Agency, which launched its five-year assessment of the state of Europe's environment in Copenhagen, Denmark, this week.

A key message is that we must prepare now for the catastrophes that will become more frequent if the world warms up as predicted. "Many of the decisions we make today will determine how we are going to live in 2050," said Hans

Bruyninckx, executive director of the agency, at the launch of *The European Environment State and Outlook 2015*.

Unlike other rich nations such as the US and Australia, Europe has embraced the reality of climate change and is blazing a trail in preparation for what is to come. The European Union has agreed to spend 20 per cent of its budget of €960 billion for 2014 to 2020 on mitigating climate change and adapting to its effects. The money is expected to boost efforts to climate-proof Europe. "Countries must decide what to use it on, and make sure it's used properly," says

Stéphane Isoard, the agency's specialist on adaptation to climate change.

Dozens of projects are already in various phases of readiness with the help of earlier funding. The top reason cited by 28 out of 30 national authorities for going

"Many of the decisions we make today will determine how we are going to live in 2050"

ahead with such projects is the impact of previous extreme weather events, according to a survey published in October. Next, for 17 out of 30, came the heavy economic costs of storm or flood damage. For example, the European Commission estimates that between 1980 and 2011, floods killed more than 2500 people and adversely affected another 5.5 million in Europe, while causing economic losses exceeding €90 billion.

As a result, 13 countries now have adaptation projects up and running, and another 33 have action plans or national adaptation strategies in place. Here, we showcase some of 60 or so projects from across the continent (see right).

Whether they will ultimately be enough to protect people in Europe will depend on the vagaries of climate change. But the costs of doing nothing could be even greater. The EC estimates that the annual cost to the EU of not adapting to climate change could rise to €100 billion by 2020 and €250 billion by 2050. Isoard can't say if it's possible to climate-proof our future, but given the success of flood management plans, for example, the introduction of the new projects is "clearly a very positive sign". ■



1 SOGN OG FJORDANE MOUNTAINS, NORWAY

HAZARD: Avalanches, landslides and flooding

SOLUTION: Early warning system. Warmer winters and unstable temperatures can cause rock slides and avalanches in unexpected locations, such as populated areas and roads. The scheme in this county aims to alert citizens and tourists at immediate risk from such hazards via landline and cellphone-based messaging systems, and social media, including Facebook.

COST: €105,000

2 NORFOLK BROADS, UK

HAZARD: Flooding from tidal surges

SOLUTION: Reinforce banks. Branded as "Britain's Magical Waterland" the Norfolk Broads are unique wetlands where flooding is likely at neighbouring properties and farmland through breaches in old peat and clay embankments. The project aims to

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COST: €160 million

3 NIJMEGEN, THE NETHERLANDS

HAZARD: River flooding
SOLUTION: Get rid of the bottleneck in the Waal river, which bends sharply

and narrows as it meanders around the coastal city of Nijmegen, causing floods. For example, in 1993 and 1995 a quarter of a million people had to be evacuated. The city is digging an extra channel, essentially broadening the river, giving it more room to flow. This will also create an urban island with new spaces for riverside recreation.
COST: €350 million



4 BERLIN, GERMANY

HAZARD: Urban heat
SOLUTION: Grow vegetation wherever possible, including on roofs and walls, to provide shade and cool the city. Under the scheme, 60 per cent of newly built public and residential areas and 30 per cent of business areas in the inner city must be reserved as "green space".
COST: Not available

5 LODZ, POLAND

HAZARD: Storm flooding
SOLUTION: Provide a "sponge" for increasingly heavy rainstorms by restoring the city's natural rivers and by building new reservoirs. During 19th-century industrialisation, rivers were turned into canals that don't soak up water as well, which led to increasingly severe floods.
COST: €1.15 billion

6 ZARAGOZA, SPAIN

HAZARD: Drought
SOLUTION: Make Zaragoza's 700,000 inhabitants more water-savvy to survive the lengthier droughts predicted for the region. Coupled with anti-leak repairs, the project has almost halved daily water use per person compared with 1980, and the city's total water consumption has fallen by 30 per cent since 1995.
COST: €2.5 million, for the public information campaign

7 VENICE, ITALY

HAZARD: Storm surges and rising sea level
SOLUTION: Build four mobile barriers at the three points where water from the Adriatic Sea enters the lagoon on which Venice is built. The barriers could be temporarily raised to block

sea surges and protect against rises of up to 60 centimetres.

COST: €4.5 billion

8 FORMER YUGOSLAV REPUBLIC OF MACEDONIA

HAZARD: Heatwaves
SOLUTION: Raise awareness. In 2007, a record heatwave in the landlocked Balkan country reached 45.7 °C causing an estimated 1000 deaths. The national action plan aims to raise public awareness and prepare the health sector to identify vulnerable citizens, and advise them on how to avoid the impact of severe heatwaves.
COST: Not available

9 CYPRUS AND GREECE

HAZARD: Forest fires
SOLUTION: Fire analysis system. Around the Mediterranean forest fires have doubled in frequency since the 1970s, to 50,000 a year. To cope, firefighters have been testing a system to predict



how a blaze will evolve. It integrates a range of data such as vegetation cover, landscape information, ignition risk and real-time weather feeds.

COST: €2.3 billion

10 DANUBE RIVER: BULGARIA, MOLDOVA, ROMANIA, UKRAINE

HAZARD: River flooding
SOLUTION: Soak up flood water by restoring 224,000 hectares of wetlands flanking 1000 kilometres of the river Danube. The wetlands were lost over the past century through dyke drainage projects in the four countries. The Lower Danube Green Corridor project aims to protect 1 million hectares of land currently vulnerable to flooding.
COST: €183 million

Shake hands, sniff palm, read signals

Catherine de Lange

YOU won't believe you do it, but you do. After shaking hands with someone, you will lift your hands to your face and take a deep sniff. This newly discovered behaviour, revealed by covert filming, suggests that humans use bodily smells to send signals, much as other mammals do.

There is evidence that the scent of women's tears lowers testosterone levels and dampens arousal in men, and that human sweat can transmit fear. But humans don't tend to go around sniffing each other, so how can we exchange information via smells?

Noam Sobel and his colleagues at the Weizmann Institute of Science in Rehovot, Israel, turned to one of the most common ways people touch each other: shaking hands. "We started looking at people and noticed that after, the hand somehow inadvertently reached the face," says Sobel.

To find out if people really do smell their hands, his team surreptitiously filmed 153 volunteers. Some were wired up to a variety of physiological instruments so that airflow to the

nose could be measured without them realising this was the aim.

The volunteers were filmed as they greeted a member of the team, either with or without a handshake. The researchers recorded how often volunteers lifted their hands close to their nose, and how long they kept them there, during the minute

before and after the greeting.

Before the greeting, both men and women had their hands near their nose 22 per cent of the time, on average. Airflow in the nose more than doubled at the same time, suggesting they were indeed smelling their hands.

After shaking hands with someone of the same sex, both men and women sniffed their shaking hand for more than twice as long as they did before the handshake. If the person was of the opposite sex, they smelled their other hand twice as long as before (*eLife*, doi.org/2jz).

The team also carried out the experiment with one of the people wearing sterile gloves. The chemicals picked up on the glove included hexadecanoic acid and squalene, both of which are involved in social signalling among dogs and rats.

It may seem counter-intuitive that the volunteers smelled their shaking hand more when they encountered someone of the same sex, but that's the wrong way to think about it, Sobel says. "We tend to think of social chemosignalling as a cross-gender story, but it's not." There are plenty of instances where signalling happens between people of the same sex, he says, such as when women's menstrual cycles become synchronised. The behaviour could also depend on the context, he suggests. In a bar, for example, the pattern might be reversed.

One surprise was just how much the volunteers smelled their hands. "When we were coding the videos we would see people sniffing themselves just like rats," says Sobel. "It's like blindsight – you see it all the time but you just don't think of it."

Charles Wysocki at the Monell Chemical Senses Center in Philadelphia says that the finding fits with the general idea that there is a lot more chemical communication going on than we are aware of. ■



Scent a deal? Not always

Key to quantum gravity may lurk in cosmic haze

SPACE-TIME'S frothy nature could be blurring the cosmos. If our views of gamma-ray bursts halfway across the universe are intrinsically fuzzy, as some predict, then the finding could help unite the twin pillars of theoretical physics: quantum mechanics and general relativity.

The two theories disagree about the texture of the universe, with

relativity saying space-time is smooth and quantum mechanics claiming it is grainy, especially on small scales. Peacemaking "quantum gravity" schemes, like string theory, are notoriously hard to test, but do predict that space-time should be frothy at close range.

This "quantum foam" would only show up at scales of 10^{-35} metres, far too small to observe directly. But it might jostle the paths of photons enough for us to observe its effects across the universe.

"They're very small perturbations, but they add up," says Eric Steinbring

of the National Research Council Canada in Victoria.

In 2003, Richard Lieu at the University of Alabama in Huntsville looked for this blurring in optical images of galaxies from the Hubble space telescope, but found nothing significant. Others have since argued that our ability to observe far more distant objects at all means the foam's effects must be weak or non-existent.

"Quantum foam might jostle photons' paths enough for us to observe its effects across the universe"

But Steinbring says that high-energy photons – belonging to gamma rays and X-rays – could be perturbed by even weaker fluctuations in the quantum foam (arxiv.org/abs/1502.03745). He tweaked the equations that describe how tiny uncertainties due to the foam add up as a photon crosses space, and compared his predictions with gamma-ray data from NASA's Fermi telescope. The results are consistent with some blurring, he says.

"I take it as a promising result," says Lieu. "Quantum gravity is the ultimate in excitement." Joshua Sokol ■

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INSIGHT US gun crime



STEVE RUARK / THE NEW YORK TIMES / REDUX / EYEVINE

Who can buy this?

When gun laws go too far

Jessica Hamzelou

LAST week, eight US professional organisations, including the American Academy of Family Physicians, the American Psychiatric Association and the American Public Health Association, collectively took a stand against a law that on the face of it seems like common sense.

For the past couple of years, psychiatrists in New York, Colorado and Connecticut have been compelled by law to report patients with mental illness to the criminal justice system. The idea is to prevent them purchasing firearms from licensed gun stores.

"These laws go too far," says Steven Weinberger, executive vice-president of the American College of Physicians. "Blanket mental health reporting laws can have unintended consequences," he says, as they can discourage people from seeking mental health care.

Philip Candilis, a forensic psychiatrist who teaches at Saint Elizabeths Hospital in Washington DC, agrees, and says that only a small proportion of gun violence can be attributed to people with mental illness. Evidence suggests that violent behaviour attributable to mental illness accounts for just 3 to 5 per cent of all violence in the US. "There is a

perception of a link between gun violence and mental health... people think 'you've got to be crazy to do that,'" says Candilis. "But it's a false perception. People with mental illness are already vulnerable to stigma, and make an easy target."

Although some states are enforcing mental health reporting, others are heading in the opposite direction. In 2013, Florida became the first state to enact "gag laws" that limit the ability of a mental health care provider to ask their patients whether they own a gun, or enter such information in a person's medical record. Missouri, where eight people died in a shooting

spree on Thursday, followed suit late last year.

These laws are "absolutely outrageous", says Weinberger. They could prevent physicians from advising parents on how to keep weapons out of the reach of children, he says.

Doctors should be free to use their clinical judgement, says Richard Bonnie, director of the Institute of Law, Psychiatry and Public Policy at the University of Virginia in Charlottesville. As far as mental health is concerned, the focus should be on improving access to treatment, Bonnie says. "Everyone agrees that access to mental health care in the US is poor."

That is also the recommendation of the draft report released by the Sandy Hook Advisory Commission. The commission aims to devise plans to prevent another massacre like the one that resulted in 26 deaths in December 2012 in Newtown, Connecticut. The report made no mention of tightening mental health reporting laws, and instead stressed the importance of improving mental health care.

In any case, it might not make a difference whether people are listed on databases – there are loopholes in US law that allow people to buy guns without background checks, for example at gun shows. These are the laws that need tightening.

"In a society as large as ours with 300 million guns in circulation, and with our culture, laws are not going to prevent every instance of gun crime," says Bonnie. "But by tightening up these laws, over time we will have an impact on gun violence." ■

Iron rain left heavy metal on early Earth

EARLY weather reports on Earth could have forecast iron rain. Our planet may have experienced such showers in its youth, which would help to explain the preponderance of precious metals in Earth's mantle and crust today.

In its formative years, Earth was probably hit by many iron-rich objects from space. Scientists previously

thought that these mostly melted into the planet's core, save for a few enormous planetesimals. These "lucky strikes" would have left iron, and elements like gold and platinum that tend to bond with iron, near the surface.

But this model was based on estimates of what happens to iron when it slams into Earth. Richard Kraus at the Lawrence Livermore National Laboratory in California and colleagues wanted to measure exactly how the element behaves under such extreme conditions.

The team used the Z machine at the Sandia National Laboratory in New Mexico to shoot aluminium plates, accelerated to high speeds, at iron samples. The resulting collisions sent powerful shock waves through the iron, eventually turning it to vapour.

The researchers discovered that it took about 40 per cent less pressure to vaporise iron than

"Incoming meteors were vaporised on impact, sending up a boiling plume of iron and rock dust"

previously thought (*Nature Geoscience*, doi.org/2jtr).

This paints a new picture of early Earth, where incoming meteors were likely to have been vaporised on impact, sending up a boiling plume of iron and rock dust. This mixture would later rain down, mixing easily and thoroughly with Earth's mantle.

Iron rain may also have brought elements like gold and platinum into Earth's rocky shell of silicate minerals, explaining why they are more common than otherwise expected.

Aviva Rutkin ■

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Drat! Where's the nectar? I was sure it was this flower

EVER remembered something that turned out to be false? Bumblebees may be prone to similar lapses.

Although bees have good memories, they have a lot to recall, including the colours and locations of flowers. "Bees make more mistakes when they juggle multiple memories than if they just focus on one flower type," says Lars Chittka of Queen Mary University of London.

Chittka and his colleague Kathryn Hunt investigated whether bees make false memories, as humans often do. This happens when an individual remembers something they haven't actually experienced – a problem for

witnesses in trials and for students, who may misremember what they were taught.

The researchers trained bees using artificial flowers that were either yellow or had a black-and-white ringed pattern. The flowers offered a nectar-like reward, but at different times. When tested within minutes of their training, bees usually visited a flower of the type that had most recently rewarded them. But as time wore on, some bees started opting for a completely new type of flower – one with yellow and white rings. The bees seemed to have become confused, merging their memories to create a false one (*Current Biology*, doi.org/2gpp).

"There might be items in a bumblebee's memory library that they have never actually encountered in real life," says Chittka.

Treating inherited disease in the womb

BABIES with a genetic disease may face a lifetime of treatment. But what if the baby's immune system could be primed for treatment before they were born?

Our immune systems are usually good at destroying foreign material in our bodies. But this doesn't apply in the womb: a study in the 1950s showed that mice undergoing skin grafts from donor mice were more likely to

accept it if they had been exposed to the donor cells as fetuses.

Sébastien Lacroix-Desmazes at INSERM in Paris and his colleagues wondered if this could help treat inherited diseases, such as haemophilia. This is caused by the lack of a clotting protein and can be treated with protein injections. But in some cases, the protein is rejected by the immune system. To see if fetal priming

could help, the team gave clotting protein to pregnant mice bred to lack it. Other similar pregnant mice received no treatment.

Once the pups were born, all were treated with protein therapy. The mice primed in the womb were much more tolerant of the protein – their immune systems produced 80 per cent less antibody against it than the unprimed mice (*Science Translational Medicine*, doi.org/2c5).

Artificial fibre as tough as spider silk

SPIDER silk is stronger than steel and tougher than Kevlar, but efforts to spin our own have so far failed to match the real thing. Now a German research group has equalled its toughness.

Previous attempts to mimic spider silk have focused on two molecules that provide its material properties. But Thomas Scheibel at the University of Bayreuth in Germany and his colleagues realised that this neglected two smaller molecules that help align the strands. His team spliced spider genes into *E. coli*, which enabled the bacteria to produce all four molecules in a bath of alcohol and water. The team then used a method called wet spinning to draw out the fibres, creating the artificial silk (*Advanced Materials*, doi.org/f253cq).

The material is not as strong as real silk, but is more elastic, so it can absorb as much energy as the real thing.

Programmable pop-up materials

NORMALLY you can rely on solid objects to hold their shape. But now there's a way to make flat surfaces pop into complex 3D shapes when heated – which could find uses from medicine to flight.

Taylor Ware at the Wright-Patterson Air Force Base in Ohio and team created a film of elastic polymers that contains a crystal lattice. Shining polarised laser light on the film changes the way the lattice is aligned, and can be used to draw a pattern. Because the crystal's thermal properties aren't the same in all directions, heating the film to 175 °C makes some parts of the pattern expand and others contract. The preplanned 3D shape formed can be 100 times as tall as the film is thick (*Science*, doi.org/2gz).

Great whites plot attacks using sun

DAA DUM! Daa dum! Great white sharks attack by positioning themselves between the blinding sun and their unsuspecting prey. It is the first empirical evidence of a non-human animal using the sun as part of its hunting strategy.

Charlie Huveneers at Flinders University in Australia and colleagues threw chunks of tuna into the water in South Australia and watched how the sharks approached when attacking.

They recorded 44 great white sharks making 1000 approaches, 37 of which were actual attacks. Sharks tended to come in from the direction of the sun: in the morning they were more likely to attack from the east and in the evening from the west. When the sun was hidden by cloud, there was no such association (*The American Naturalist*, doi.org/2gv).

It could be that the prey are better lit that way, or perhaps their view of the shark is obscured by the glaring sun. "With the sun in the eyes of the prey, their pupils contract," says Rob Harcourt at Macquarie University in Sydney, Australia.

"I surf every day at Bondi [beach] and in the mornings the sun is rising over the water," says Harcourt. "The sun is a lot brighter above the water so hunting that way would make sense."



BRIAN J. SKERRY/NATIONAL GEOGRAPHIC CREATIVE

Future-predicting neurons discovered in the brain

LEAN in for a kiss. Am I into it or will you get a slap? Interacting socially requires us to predict others' intentions. Now we know which brain cells allow monkeys – and possibly humans – to do this.

Keren Haroush and Ziv Williams at Harvard Medical School trained monkeys to play a version of the prisoner's dilemma, a game used to study cooperation. The reward – in this case, drops of juice – depends on whether or not both parties individually opt to cooperate. Once both monkeys had made their decision, they

could each see the other monkey's choice. Like humans, they were more likely to cooperate if their opponent had recently cooperated with them.

During the experiment, Haroush and Williams recorded brain activity from single cells in the monkeys' anterior cingulate – an area involved in decision-making. They found that the activity of a specific set of neurons was associated with the monkey's own decision in each game.

But anticipating an opponent's action is key to maximising the

reward. The pair found another set of neurons in the same area that seemed to predict what a monkey's opponent intended to do – before they did it.

In fact, when they looked back at the results, in 79 per cent of trials, the activity of the neurons in one monkey predicted the next move of the other (*Cell*, doi.org/2gn). They say that unlike mirror neurons – which are active when observing an action or performing the same action as another – these neurons try to predict the intentions of others.

Prehistoric Britons loved flat bread

PREHISTORIC people living on the British Isles were more than hunter-gatherers: they were bakers, too. They seem to have been eating wheat 2000 years before arable farming started on the islands.

Robin Allaby at the University of Warwick, UK, and his team found wheat DNA dating back some 8000 years in mud at a now submerged Mesolithic shipyard near the Isle of Wight, off the southern coast of the UK (*Science*, doi.org/2gs).

But no pollen turned up, which suggests that the wheat wasn't being grown there. A lack of husks and seed casings also implies the wheat wasn't ground at the shipyard, and was instead imported as flour.

The closest wheat farmers at this time were probably in southern Europe or the Near East. "Rather than being cut off as the commonly held view states, these hunter-gatherers had trade links to distant agricultural communities," says Allaby.

It is likely that the boat builders had a fondness for flat breads to complement their protein-rich diet of game and foraged nuts and plants, says Allaby.



NASA/JPL-CALTECH/MSSS

For clues to Earth's climate, drill Mars

DIGGING a hole on another world may settle a nagging question about Earth's climate.

From about 1300 to 1870, much of the Earth endured a long cold snap dubbed the Little Ice Age. The freeze is usually blamed on a dip in solar activity, but there are other suspects such as volcanoes.

If the sun was responsible, we should see evidence of it across the solar system, says Ralph Lorenz of the Johns Hopkins University Applied Physics Lab in Laurel, Maryland. To settle the debate, he suggests digging a hole on Mars to see if it, too,

had an ice age around that time (*Icarus*, doi.org/2g2). Temperature changes propagate downward through ice and soil, so a borehole will contain clues to past climate. The ice cap in Greenland contains signals of the Little Ice Age around 60 metres deep, for instance.

Drilling a hole on Mars is already on the cards: NASA's 2016 InSight lander will drill 5 metres into Martian soil. That might be deep enough to find a hint of an ice age. For the full signature you would need to dig down 40 metres, but it could be much shallower in certain soils.

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Film night of the future

Enter the reel world

The virtual reality boom is about more than just gaming – it could revolutionise how we watch films. **Jacob Aron** jacks in

I'M SAT in a deckchair relaxing on the beach, watching the sun go down. I would happily have stayed there for a good while, but my time is up and I have to return to the real world. When I remove the Oculus Rift headset and headphones, the noisy conference room comes as a huge shock.

I had been experiencing *Perfect Beach*, a virtual reality (VR) experience created by developer nDreams in Farnborough, UK. The firm was showing off its creation at the SouthWest VR conference in Bristol last week, where game developers,

film-makers and visual-effects artists came together to discuss how VR experiences could improve films and games.

The rise of VR headsets in recent years has been led by game developers seeking a way to immerse players even deeper in virtual worlds. But adding VR to a video game can actually hamper play, because the goggles stop you seeing the controller in your hands.

Yet the ability to put someone in a space and give them limited but meaningful interaction provides a new experience –

one that could shake up the film industry.

"The thing I find really engaging about VR is the sense of presence," says Dave Ranyard of Sony Computer Entertainment Europe, who is developing software for Sony's upcoming VR headset, Morpheus. "It feels like a step change in immersion."

One of the big hits at the Sundance film festival in Utah in

"The brain accepts virtual film as a social interaction, rather than something that's seen on a screen"

January was *Wild: The Experience*, a 3-minute virtual reality version of the film *Wild* starring Reese Witherspoon, in which viewers can watch from all directions. VR firm Oculus has also set up a VR film division called Story Studio to produce short films for the latest version of its headset.

But VR film-making doesn't have to be a blow-out Hollywood extravaganza to work; even simple films, like my deckchair experience, can be surprisingly convincing. "In any other medium this would be boring, you wouldn't sit there for 10 minutes," says Nick Pittom of VR firm Fire Panda. But it's narrative experiences where VR will really shine, he says – if a static VR scene can be powerful, a story will be even more so.

As VR film is a new medium there are no set rules. Phil Harper of Alchemy VR, a UK firm working

on immersive natural history films with veteran broadcaster David Attenborough, calls his nature documentaries 360° video, because they are made by arranging a number of cameras in a sphere and stitching the resulting videos together to create an all-encompassing film. Watching someone speak to you in VR is more intimate than on a TV screen, he says, because they appear to be the same size as a real human. "The brain begins to accept this as a social interaction, rather than something that's seen on a screen," Harper says.

Nowhere to hide

But this approach has its challenges. Because audiences can see all around them, it is impossible to hide equipment that would normally sit just out of shot. Even directors have to face their audience, or else hide. "Often I'm just stood in the background," says Harper. "You can't hide anything in 360° video."

In some situations that can free viewers of a framing camera's deception. "360° video is a truly honest format," says Harper, who thinks news broadcasts in particular could benefit. Earlier this year Vice News gave the first VR news report from a protest in New York.

For fictional stories, film-makers might want a different

approach. One option used by Belgian VFX firm Nozon is to render high-quality 3D worlds on a computer and then "film" inside them, without having to worry about having equipment on show. This 360° CGI is convincing – Nozon's Matthieu Labeau showed me a short but incredibly lifelike clip in which a robot and a beaver hang out in an ornate ballroom.

Both 360° CGI and 360° video have the same problem, though: they can't react to the audience. Limited interaction, like selecting different scenes based on where you look, is possible, but that's about it. Viewers also tend to look straight ahead, so you have to cue them to look elsewhere with particular sounds or pointing characters. "I don't think a movie where things are happening all around you makes sense, because you will feel you missed half the movie," says Labeau.

That's where game engines, the software that powers gaming's 3D worlds, can help. Visual quality takes a hit because rendering happens in real time, but that also allows for a more interactive experience, heightening immersion. You can place a scene to the left of the viewer and encourage them to turn their head, but if they don't take the hint the characters can move directly into view, says Pittom.

He recently recreated scenes from animated Studio Ghibli

films in a game engine to let people explore them in VR, a technique that is also finding its feet in the film industry (see "The director's cut", below left).

But Pittom says the language of film – close-ups, fast cutting and so on – doesn't translate well to VR. Instead, in some ways the closest existing medium is the interactive theatre pioneered by Punchdrunk, in which there is no stage and the audience directly interacts with actors and chooses which parts of a scene to watch. But VR can create realistic worlds that are impossible in theatre. "It's the difference between watching a kitchen-sink drama and the film *Avatar*," Pittom says.

But are consumers ready for a new kind of film that requires new hardware, having so recently been

"A cardboard headset that you slot your phone into might be all you need to experience virtual reality"

burned by the 3DTV and film fad? Some VR experiences need very powerful PCs for the full effect, so the outlay could be enormous.

"The demand already exists but the technology doesn't," says Harper. Unlike 3DTVs, which were pushed by television manufacturers, the growth in VR tech is being driven by consumers, particularly through crowdfunding – though that has led to delays in getting products on shelves. But with the ubiquity and increasing power of smartphones, a cheap cardboard headset that you slot your phone into might be all you need to take your first steps into VR.

Whether as films, games or something in between, there is a lot of confidence that VR experiences are finally here to stay. Ranyard even thinks that VR could be a defining part of the 2010s, as the Walkman was for the 80s. "I think people wearing a VR headset and experiencing something is going to be an iconic image." ■

ONE PER CENT



Hack your garden

Revolution Bio, a biotech start-up in Fort Collins, Colorado, plans to sell petunias that repeatedly change colour. Their DNA has been reshuffled to link the genes that control flower colour to a set that only switch on during the day. The result is a flower that, for example, blooms pink in the morning and changes to blue by nightfall.

37.9

The percentage of the world population who access the internet at least once a year. Facebook's *The State of Global Connectivity* report adds that the rate at which the total number of users is growing every year has declined, from 14.7 per cent in 2010 to 6.6 per cent last year.

Smart food

Want to make sure your milk is fresh? Two new London start-ups aim to change the way food is packaged. Zyme Deal coats the inside of drinks packaging with a polymer to extend shelf life. Fresh Sense's packaging changes colour when it senses that the food inside has been contaminated. Both groups are part of the Imperial Create Lab at Imperial College London.

THE DIRECTOR'S CUT

Hollywood is embracing virtual reality not just for audiences, but for directors who want a new view of the action.

An important step when making a movie is previsualisation, when film-makers create low-cost versions of the film before spending millions of dollars on the real thing. That used to involve scale models and storyboards, but now includes 3D animations of key sequences.

Duncan Burbidge of The Third Floor in London, which helps

film-makers with previsualisation, says the film is now experimenting with adding virtual reality to these 3D animations, so directors can explore a location and plan out their shots.

"These days sets are becoming increasingly virtual," says Burbidge, making it harder for directors to let their creative juices flow. Virtual reality changes that, he says. "Their eyes light up like a Christmas tree and they're suddenly engaging with it in a way that they're used to."

Facebook's exam for machines

Making your AI take a storybook quiz vastly improves on the Turing test, says **Jacob Aron**

JOHN is in the playground. Bob is in the office. Where is John? If you know the answer, you're either a human, or software taking its first steps towards full artificial intelligence. Researchers at Facebook's AI lab in New York say an exam of simple questions like this could help in designing machines that think like people.

Computing pioneer Alan Turing famously set his own test for AI, in which a human tries to sort other humans from machines by conversing with both. However, this approach has a downside.

"The Turing test requires us to teach the machine skills that are not actually useful for us," says Matthew Richardson, an AI researcher at Microsoft. For example, to pass the test an AI must learn to lie about its true nature and pretend not to know facts a human wouldn't.

These skills are no use to Facebook, which is looking for more sophisticated ways to filter your news feed. "People have a limited amount of time to spend on Facebook, so we have to curate that somehow," says Yann LeCun, Facebook's director of AI research. "For that you need to understand content and you need to understand people."

AI plays 20 questions

In the longer term, Facebook also wants to create a digital assistant that can handle a real dialogue with humans, unlike the scripted conversations possible with the likes of Apple's Siri.

Similar goals are driving AI researchers everywhere to develop more comprehensive exams to challenge their machines. Facebook itself has created 20 tasks, which

get progressively harder – the example at the top of this article is of the easiest type. The team says any potential AI must pass all of them if it is ever to develop true intelligence (arxiv.org/abs/1502.05698).

Each task involves short descriptions followed by some questions, a bit like a reading comprehension quiz. Harder examples include figuring out whether one object could fit inside another, or why a person might act a certain way. "We wanted tasks that any human who can read can answer," says Facebook's Jason Weston, who led the research.

Having a range of questions challenges the AI in different ways, meaning systems that have a single strength fall short.

The Facebook team used its exam to test a number of learning algorithms, and found that none managed full marks. The best performance was by a variant of a neural network with access to an external memory, an approach that Google's AI subsidiary DeepMind is also investigating. But even this fell down on tasks like counting objects in a question or spatial reasoning.

Richardson has also developed a test of AI reading comprehension, called MCTest. But the questions

in MCTest are written by hand, whereas Facebook's are automatically generated.

The details for Facebook's tasks are plucked from a simulation of a simple world, a little like an old-school text adventure, where

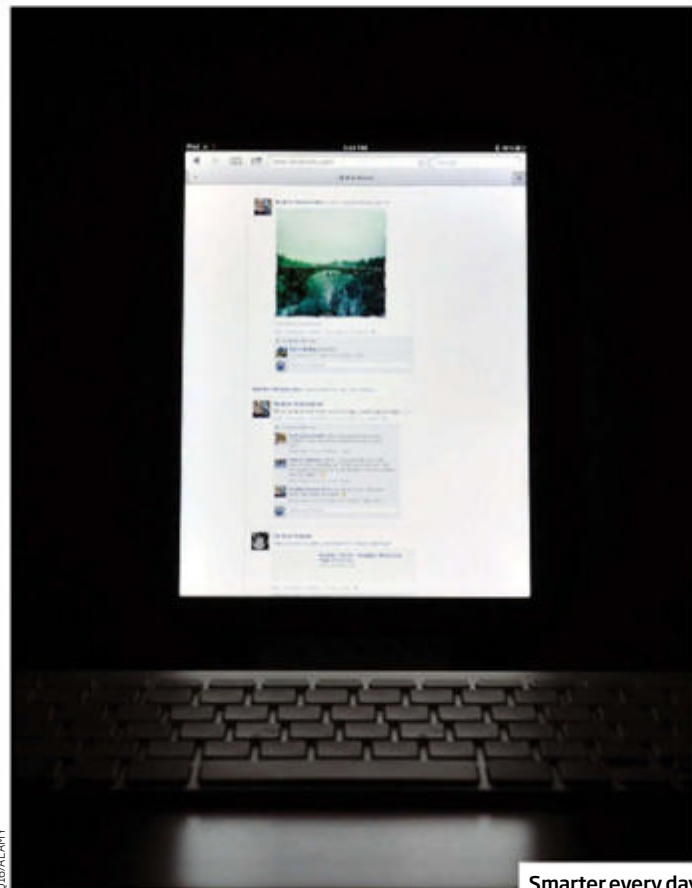
"In the long-term, Facebook wants a digital assistant that can handle a real dialogue with humans"

characters move around and pick up objects. Weston says this is key to keeping questions fresh for repeated testing and learning.

But such testing has its problems, says Peter Clark of the Allen Institute for Artificial Intelligence in Seattle, because the AI doesn't need to understand what real-world objects the words relate to. "You can substitute a dummy word like 'foobar' for 'cake' and still be able to answer the question," he says. His own approach, Aristo, attempts to quiz AI with questions taken from school science exams.

Whatever the best approach, it's clear that tech companies like Facebook and Microsoft are betting big on human-level AI. Should we be worried? Recently the likes of Stephen Hawking, Elon Musk and even Bill Gates have warned that AI researchers must tread carefully.

LeCun acknowledges people's fears, but says that the research is still at an early stage, and is conducted in the open. "All machines are still very dumb and we are still very much in control," he says. "It's not like some company is going to come out with the solution to AI all of a sudden and we're going to have super-intelligent machines running around the internet." ■



OJG/ALAMY

Smarter every day



GET INSIDE YOUR OWN HEAD

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Frozen in dirt

THIS grey kangaroo probably died from starvation at the peak of Australia's recent 15-year drought, and then quickly became half-buried in the country's iconic red dirt, carried in scorching dry winds blowing across the desert.

It was those winds that, in 2009, blanketed Australia's east coast in an eerie red cloud - what became known as the East Australian dust storm. When photographer Dean Sewell saw the spectacular storm engulf Sydney, he decided to head west and investigate its source.

He came across this dead kangaroo in Tibooburra, one of the places the dust was found to originate, about 1200 kilometres north-west of Sydney. "There was no vegetation out there at all," says Sewell. "It was as bare as you've ever seen it. And daily there were dust storms blowing around."

This image forms part of a lifelong project to examine the region, known as the Murray-Darling basin after one of Australia's most significant river systems. Sewell says he returns again and again to capture the consequences of climate change and human activity.

The photograph is on display as part of the Syngenta Photography Award 2015: Scarcity-Waste exhibition at Somerset House in London from 11 March to 10 April. Michael Slezak

Photographer

Dean Sewell Oculi
oculi.com.au

Siege mentality

Hostility to immigration has deep roots in human psychology that will be difficult to overcome, says **Victoria Esses**

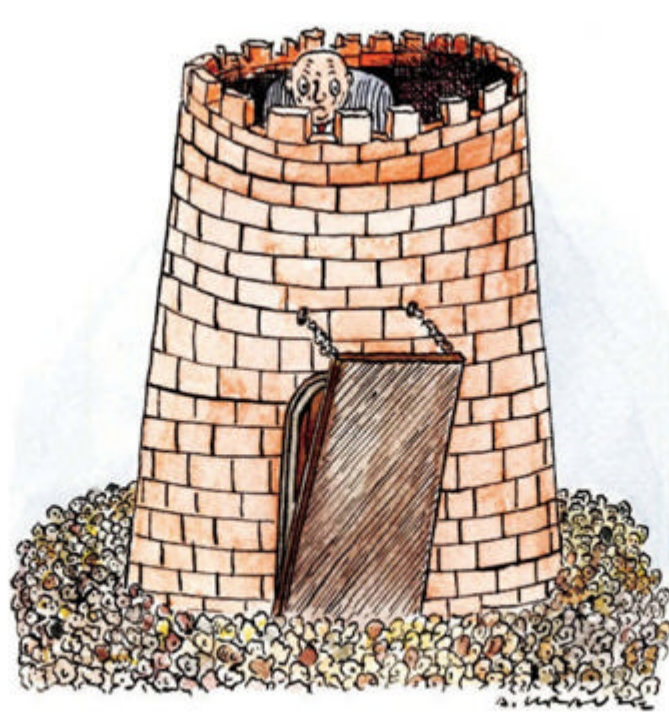
IN SEPTEMBER 2014, the US faced a crisis. Tens of thousands of unaccompanied children from Central America had crossed the Mexican border illegally and were being held in detention centres. There were polarised, angry debates on how to respond. President Obama called the issue a “humanitarian crisis” and worked to house and feed the children. Others opposed using US resources to care for them.

Around the same time, a row erupted in Europe over migrant ships in the Mediterranean. Italy suspended its rescue missions and the UK refused to support a new European Union search and rescue operation, claiming it would encourage more migrants to attempt the crossing. Aid agencies and the UN High Commissioner for Refugees retorted that such operations were necessary to save lives.

International migration is one of the major social issues of the day. More people live outside their country of birth than at any other time in history – 232 million in 2013 – and this number is expected to carry on rising.

The swell in migration is the result of many global trends, including growing inequalities between nations, demand for labour in countries with a falling birth rate and a rise in the number of refugees and asylum seekers.

Opposition to immigration is widespread in many Western nations. Anti-immigration activists, the media and political elites have created a crisis mentality in which immigrants are portrayed as “enemies at the



gate”. Immigrants – particularly non-whites – are blamed for all of society’s woes. Such depictions encourage support for more extreme political platforms.

Even legal immigration has become controversial, with groups such as the UK Independence Party proposing stricter controls on migrants from certain parts of the EU.

Psychologists have much to contribute to the understanding of what may be driving these attitudes and behaviours. Yet, with a few exceptions, we have been slow to enter the field.

We are not starting from scratch. Attitudes and prejudices have been studied for decades,

and there are experimental methods for probing their underlying causes.

One especially pertinent area of research looks at the perceived role of competition in intergroup relations. Psychologists have been debating this for many years. In the context of immigration, it turns out to be very important.

As a rule, members of socially dominant groups tend to believe that their group is superior and hence entitled to resources and privileges. To maintain their

dominance, they must fend off “invading” groups who are seen as competing with them for finite resources including jobs, political power and cultural and religious influence. This can occur irrespective of whether there are indeed limited resources and actual competition over them.

This belief in zero-sum competition is central to attitudes about immigration. There is a widespread belief that any gains immigrants make must be at the expense of members of the host society. This belief is deeply embedded in Western society, even though it is seldom justified.

The upshot of these attitudes is hostility toward immigrants, self-aggrandisement – often in the form of nationalism – and support for the exclusion of immigrants and refugees.

When migrants are allowed to settle in a new country, they are often faced with a “damned if they do, damned if they don’t” dilemma. If they are economically successful, they are seen as having taken jobs or opportunities away from local people; if they are not successful, they are seen as a drain on the system.

Refugees and asylum seekers are especially likely to be treated with hostility. Research has shown that common themes in the media – including claims that asylum-seekers are “bogus” and associated with criminals, terrorists and disease – leads to dehumanisation. This perception allows some in the host nations to assert that refugees deserve the unfair and inhumane treatment they receive.

“More people live outside their country of birth than at any time and the number will carry on rising”

These reactions ebb and flow depending on external factors that increase uncertainty and anxiety, and challenge the status quo. Economic recession, natural disasters and demands for equal rights for migrants can exacerbate perceptions of zero-sum competition and threat from outsiders. The Ebola outbreak, for example, helped to fan the flames of anti-immigration sentiment against Hispanics in the US, even though there were no cases of Ebola in Latin American countries.

Changing these attitudes is not easy. We know that just telling people that immigrants are not taking resources can backfire. This may occur because zero-sum beliefs are so deeply embedded and well defended.

Change may be easier in nations built on immigration, such as Canada, the US and Australia. Focusing on their history, on what today's immigrants have in common with yesterday's, and on the benefits that immigrants bring can help forge a common identity and more positive attitudes.

However, this will not work in nations, such as the UK, that do not see themselves as being built on immigration. In these countries, attempting to describe immigrants as part of the national in-group may simply reinforce negative attitudes.

What is abundantly clear is that immigration and asylum-seeking are not going away. Countries that integrate immigrants successfully are less likely to feel the stress and more likely to reap the benefits. Many have recently come to this realisation and are implementing new policies: President Obama's Task Force on New Americans is an example. Those countries that simply try to slam the door shut are asking for trouble. ■

Victoria Esses is professor of psychology and director of the Centre for Research on Migration and Ethnic Relations at the University of Western Ontario in London, Canada

ONE MINUTE INTERVIEW

When autism wears a mask

More women have autism spectrum disorders than people think, says **Hannah Belcher** – we're just better at hiding it



PROFILE

Hannah Belcher is a PhD student in psychology at Anglia Ruskin University, UK, who was diagnosed with Asperger's syndrome at age 23. She is conducting an online survey to better understand possible misdiagnoses in females

What led to you being diagnosed so late?

I'd had a lot of isolated problems that nobody had really pieced together as I was growing up. I was in therapy when somebody finally said: "I think all these difficulties you've been having could actually be autism rather than mental illness."

How did you react to that idea?

It was a massive shock. Despite studying autism in my psychology degree, I had never considered I might have a form of it. That's also when I realised that there is a big issue with diagnosis in general.

Did things make sense to you at that point?

Definitely. At first I thought: I have friends, I socialise, it can't possibly be that. But underneath I'm having the same problems: a lot of anxiety, especially in social situations, and problems like sensory overload. I realised I'm just masking it a lot.

So that led to your current research?

Yes, I wanted to find out how many other females are out there who are also masking

their symptoms and so haven't been discovered yet, just because what they are displaying isn't stereotypical autism spectrum disorder (ASD) behaviour. My research involves a nationwide screening project and anybody, male or female, can take part at psychscreen.co.uk.

How might women be masking symptoms?

Females are placed under a lot of pressure to fit in, and I think that drives us to develop coping mechanisms. I read a paper on memory that said female brains are naturally better than male ones at storing up scripts in social situations. When I was growing up, I would observe people around me, see how they were behaving, and develop a script to get myself through it. Also, when females with ASD get an obsession it's not typically with the same things that males with ASD get into. I've never been interested in trains or timetables – I'm not collecting information. I was obsessed with more normal things.

What do you get obsessed with?

When I was younger it was music – I would listen to the same song over and over and drive everyone up the wall. Now I'm obsessed with psychology.

What would an earlier diagnosis have meant?

I dropped out of school when I was 14 because I couldn't cope with the pressures. With a diagnosis, that wouldn't have happened – I would have had the correct support. I think a lot of undiagnosed females develop other mental health conditions because of the pressure they are under. Only a fifth of girls with ASD are diagnosed before the age of 11, compared with over half of boys with it, so I think there are probably more girls with ASD than we realise.

Having left school so young, how did you manage to turn yourself into a researcher?

I'm not very good in a group or at understanding people, so I found it easier to teach myself. I taught myself GCSEs, A levels and most of my degree. It was just second nature to me.

Interview by Catherine de Lange

A close-up portrait of Denise Kandel, an older woman with short, wavy brown hair. She is smiling slightly and looking towards the right. She is wearing a dark, textured jacket over a red top. A red and silver earring is visible on her left ear. The background is a plain, light gray.

PROFILE

Denise Kandel is a professor of sociomedical sciences at Columbia University's Mailman School of Public Health in New York City. For 50 years she has explored risk factors for drug use and addiction

Sentinel at the gates of addiction

The idea that cigarettes prime the brain for addiction to harder drugs has long been controversial. Epidemiologist **Denise Kandel** explains how she found hard evidence

Photographed for New Scientist by Mike McGregor

It's the 40th anniversary of the gateway drug theory. What led you to propose it?

There had been a large increase in the use of marijuana in the 1970s. I was funded to do a project focused solely on marijuana, but I thought that it might also be interesting to look at other drugs, so I slipped some questions about drinking and smoking into the interviews.

Once I started looking at the data, I realised that there were certain ages at which people tended to get involved in different classes of drugs. They tended to start on cigarettes, alcohol and marijuana at around ages 12 to 14. By doing cross-sectional and longitudinal studies of drug use, I found the same pattern over and over again.

What was that pattern?

People started with legal drugs such as wine, beer and cigarettes, and some progressed to marijuana. Then some moved on to cocaine, and then, perhaps, to heroin. Of course, this doesn't mean that just because you smoke cigarettes, you are going to become a heroin addict. But it was – it is – a very compelling pattern. I proposed that cigarettes and alcohol were gateways to the use of illegal drugs. This created a lot of controversy.

You finally put your theory to the test last year in a collaboration with your husband, neuroscientist and Nobel laureate Eric Kandel. How did that come about?

For years, I'd suggested that a rodent model was needed to better understand what might be driving this pattern. Then, a decade ago, I was invited to go to a meeting in Prague organised by the Society for Research on Nicotine and Tobacco, so I asked my husband if he would like to come. He said yes, and when I told the organisers, they asked if he would give a basic science lecture. He had done some work on cocaine – nothing to do with the gateway theory – and he talked about that.

After his lecture, I said, "You know, Eric, I think we should do something in mice looking at the impact of nicotine on the response to cocaine." That was how it started. If we hadn't gone to the meeting together, if he hadn't given that lecture, it might never have happened.

You found a strong neurological basis for the gateway effect. Were you surprised?

As I said, I didn't think that the pattern of use was random. But testing the idea empirically in humans was a challenge. You can't propose a study where you say, "I am going to present

cigarettes and cocaine, in different orders, to a group of kids to see if they are more or less likely to want to snort cocaine after having tried cigarettes." But you can do something along those lines in mice.

When we did that study – and we looked at the behaviour, the neurobiology and the molecular biology – we found a strong gateway effect: when you primed a mouse with nicotine and then exposed it to cocaine, the effects of cocaine were enhanced. We saw more addiction-like behaviours in those mice, and my husband's laboratory saw changes at the molecular level.

What sort of brain changes emerged?

Just one example is that nicotine enhances the expression of *FosB*, a gene involved in reward. Such changes make the brain more receptive to experiencing the rewards of another drug.

"People aren't talking about effects of e-cigarettes on the brain, but it's important"

What surprised us was that this effect was completely unidirectional: when we did the reverse and primed the mice with cocaine and then introduced them to nicotine, there was no effect on nicotine at all, either in behaviour or at the molecular level (*NEJM*, vol 371, p 932).

Were there any other surprises?

Yes, another unanticipated finding in our mouse data was that we only saw the gateway effect when exposures were overlapping – when mice were primed with nicotine and then had at least one day where they were exposed to both nicotine and cocaine. This suggested that people have to be actively smoking when they start using cocaine for these brain changes to occur.

I went back and re-examined the epidemiological data and found that, in the overwhelming majority of cases, young people were actively smoking when they started using cocaine. And the rate of addiction was twice as high among those who were smoking when they started using cocaine as among those who were not smoking at the time.

It sounds like a fertile marriage of two very different disciplines...

The work exemplifies how you can move from epidemiology to the biology lab and back again. The two fields have a lot to offer one another – if scientists are open to it.

E-cigarettes and vaping are gaining popularity, touted as "safe" alternatives to smoking.

What are your thoughts on this?

It is a controversial topic. You need to keep in mind that there are two types of e-cigarette consumers: people trying to stop smoking, and young people trying something new.

If you're an established smoker, vaping might be a safer alternative because you aren't exposed to all the carcinogens that cigarettes produce. But e-cigarettes are unregulated and may contain all kinds of compounds and chemicals that we do not know about.

Perhaps most importantly, the current safety discussions in the medical community emphasise the effects of these products on the lungs and heart. People aren't talking about effects on the brain. Our work suggests this is important. Nicotine is nicotine, whether from a cigarette or an e-cigarette. And when it gets into the brain, especially the adolescent brain, there are negative consequences.

We are learning that the rates of use of e-cigarettes are growing dramatically, especially among young people. What is driving that? The science is not keeping up with rapidly changing behaviour.

Your initial work on the gateway theory also suggested that marijuana is a gateway drug.

Over the years, people tended to focus on marijuana being *the* gateway drug, the substance that would ultimately lead you to cocaine or heroin. Indeed, that link does not appear to have weakened over time – but that wasn't exactly what I was saying. My research described a link from tobacco or alcohol to marijuana, and then from marijuana to cocaine. The connection between alcohol and cocaine, and between cigarettes and cocaine, is extremely strong.

How might your new work translate into public health measures to tackle drug use and addiction?

Drug addiction stems from a constellation of factors. We know that genes are important, and so is environment. If you are susceptible to becoming addicted, then it isn't safe to use any drugs. We have known for a long time that you have to start any intervention early for it to be successful. Our work provides a strong rationale for doing so. If you can get young people to not use tobacco or other substances, if you can educate them about the effects on the brain, you can reduce the risk – and, with luck, make a difference. ■

Interview by Kayt Sukeil

THEY call it “the desert” – a vast, empty landscape separating us from a promised land that shimmers like a mirage on the horizon. A land full of answers, where we finally achieve a complete understanding of material reality.

Stop dreaming: we can’t get to this nirvana. The way across the desert is too long and hot, and we have no vehicle to take us there. But if physicists’ hopes are realised, a machine just waking from a two-year slumber could bring us a decisive step closer – and might even reveal answers closer to home.

The machine in question is the Large Hadron Collider, or LHC. This most muscular of particle smashers, situated at CERN near Geneva, Switzerland, garnered fame for discovering the Higgs boson in 2012. That was the last uncharted feature of a landscape that’s now pretty well explored: the landscape of the standard model, our current best theory of matter and its workings.

Since February 2013, the LHC has been undergoing a comprehensive overhaul.

It’s back

After a two-year makeover, could the rejuvenated LHC spy even wilder particles, asks **Matthew Chalmers**

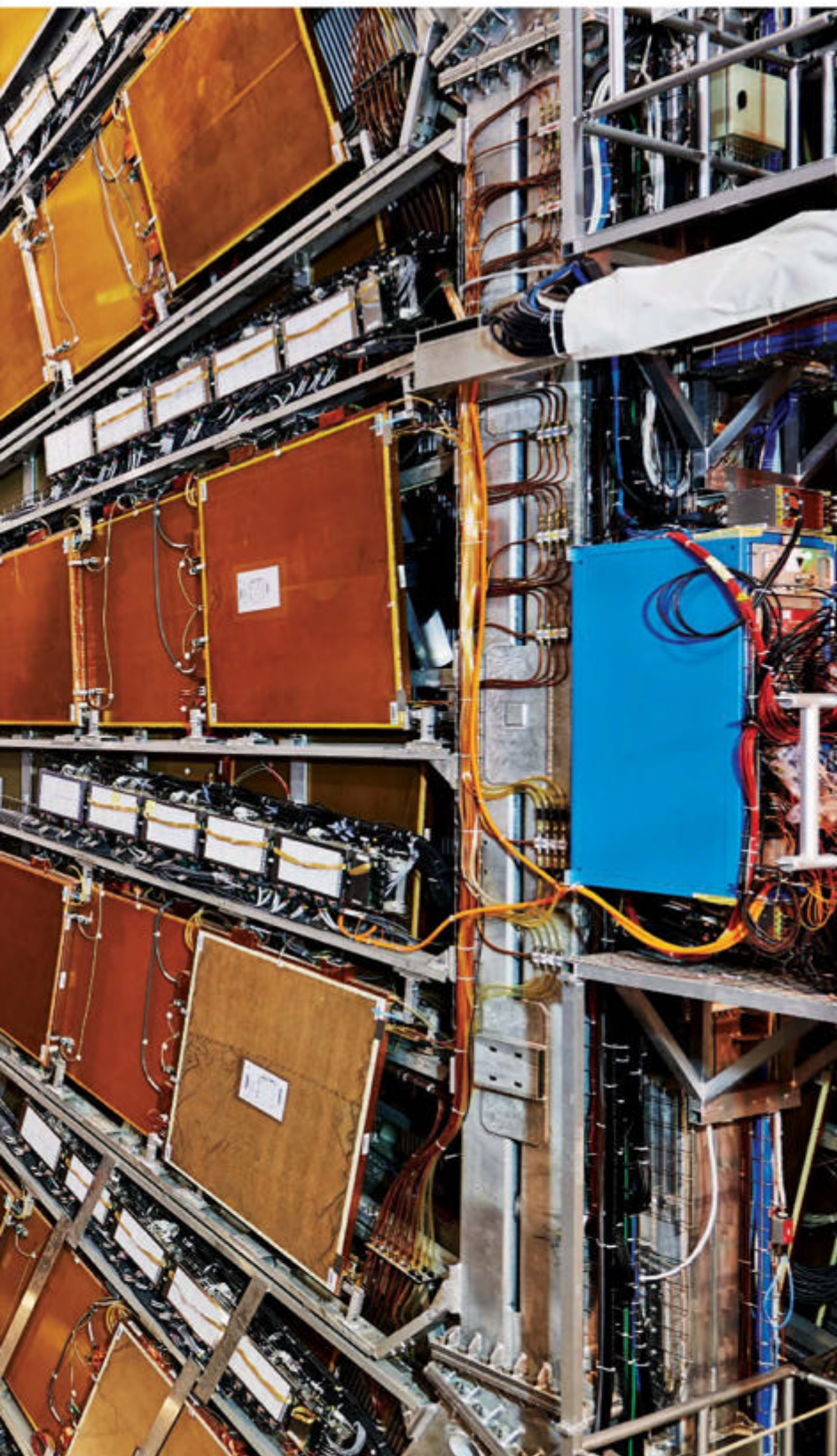
Now it is gearing up again, more powerful than ever before, for a journey towards the desert – and the complete unknown. The excitement is palpable. “We are living in a once-in-a-lifetime experience, opening the curtains on a totally new energy scale,” says Jim Olsen of the LHC’s CMS experiment.

Particle physicists measure out territory using energy as their yardstick. Through Einstein’s famous equation $E = mc^2$, smashing particles together at high speed converts their mass into pinpricks of enormous energy that can in turn form other, more massive particles. Our universe started out in a hot, dense big bang, so the higher the energies we reach by ramping up the speed of the colliding particles, the further back we reach into the origins of the cosmos and matter itself.

In this way the LHC and its predecessors have allowed us to map out the standard



ENRICO SACCHETTI



model. This theory describes the fundamental particles of matter, known as leptons and quarks, and the particles responsible for transmitting three of the four forces operating on them: electromagnetism and the weak and strong nuclear forces.

The crowning glory of this effort was the Higgs boson. This particle represents a disturbance in an all-pervasive, invisible entity, the Higgs field, with which all other fundamental particles interact to acquire their mass. The Higgs is essential to explain a pivotal moment in the early cosmos. Originally, electromagnetism and the weak nuclear force were part of the same unified electroweak force, until the Higgs field switched on around 10^{-12} seconds after the big bang. This “broke the symmetry” of the force, giving the particles that transmitted it different masses. Since that point electromagnetism, carried by the massless photon, has had an effectively infinite range, whereas the weak force, carried by the meaty W and Z bosons, has been confined to the subatomic scale.

Complete yet incomplete

The Higgs’s existence was first predicted in 1964, but finding it required the energy of the LHC: 8 teraelectronvolts (TeV) produced in head-on collisions between protons. Even then, theorists were not certain about exactly what mass the Higgs should have, assuming it did exist. But it was a no-lose situation: even if it did turn out to be a mathematical mirage, they would have had the impetus to tear up the standard model and start afresh.

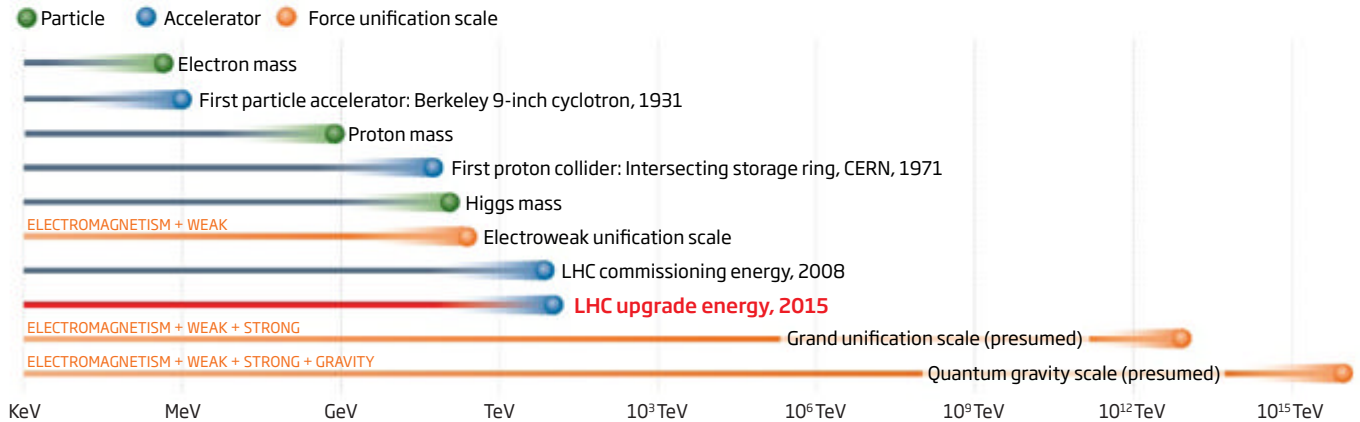
As it was, the elusive particle was found with a mass of 125 gigaelectronvolts (GeV), well within the LHC’s energy range. Theorists were vindicated and two of the Higgs theory’s pioneers, François Englert and Peter Higgs, shared the crowning glory of physics, a Nobel prize, in October 2013.

But here’s the thing: although the standard model is now complete, it is incomplete. The theory includes no description of dark matter – a sizeable omission, given that this stuff apparently makes up 85 per cent of all matter in the universe, judging by observations such as how galaxies move as if whirled around by an invisible gravitational hand. It gives no indication of how a tiny imbalance could have arisen between normal matter and antimatter to ensure a matter-filled cosmos. It is also mute on gravity, the fourth of the four fundamental forces.

More technically, the standard model is dependent on a bevy of arbitrary numbers ➤

Unscalable heights

Particle accelerators have conquered many new frontiers – but are still far short of the energies at which the forces of nature become unified



to make it work. The Higgs is just one example: its mass is one of many quantities the standard model cannot predict, but which have to be measured instead. Left to its own devices, the model does come out with a number of sorts: it says the Higgs interacts so strongly with heavy particles that it acquires a nonsensically large mass of at least 10^{13} TeV.

For most physicists, the conclusion is that the standard model is part of a bigger theory – one that brings us closer to unifying all forces and understanding matter at all energy scales. The problem is, although precise predictions vary, our best guess is that further bouts of force unification only lie at scales of trillions of TeV and above, that were last attained in the first trice of the universe – within 10^{-36} seconds of the big bang (see diagram, above).

No accelerator on Earth could conceivably achieve such energies. In this picture, what lies between us and the unattainable promised land is a desert devoid of interest. It makes the LHC's upgraded collision energy of 13 TeV seem a rather forlorn gesture.

Not so, says theorist Ben Allanach of the University of Cambridge. If the favourite candidate for a next-generation theory is right, the sliver of new territory we are about to enter could contain particles and phenomena that will take us a decisive step closer to an ultimate answer.

The theory in question is supersymmetry, or SUSY to its friends. First dreamed up in the 1970s, SUSY provides the first whiff of a “grand unified theory” that combines the electroweak and the strong forces. It pulls off this trick by introducing a forest of “sparticles”, heavier supersymmetric doppelgängers for each particle already known, that might appear at scales the LHC

can probe. “If they find signals of a new particle at the LHC you will see a shock go through the theoretical community,” says Allanach. “We’ll be dancing in the streets.”

Not least because the lightest sparticle provides an excellent candidate for dark matter. In concert, the sparticles also naturally cancel out troublesome quantum fluctuations that cause the Higgs mass to balloon out of control. A dark-matter-like SUSY particle is likely to slip unseen out of the detectors, leaving a hole when adding up the energy and momentum produced. But, in general, SUSY particles are expected to make themselves known by the way they decay into lighter standard model particles in telltale patterns.

So beloved of theorists is SUSY, and so earnest is the desire to catch a glimpse of it, that several safeguards must be built into the analysis procedure to guard against

“No accelerator on Earth could achieve the energies needed to unify the forces”

overenthusiasm. Once the crew is confident the machine and the analysis are running smoothly, the data will be “blinded” – computers doing the analysis will not read out the results of certain calculations until sufficient data has been accumulated, to prevent standard model processes being misinterpreted as something new (see “Faster, higher, stronger”, right).

To confirm an anomaly is the result of fresh physics, it must be present in data from both of the two big LHC experiments, ATLAS and CMS, as was the case for the Higgs discovery. “The moment where fluctuations deepen and are mutually confirmed is

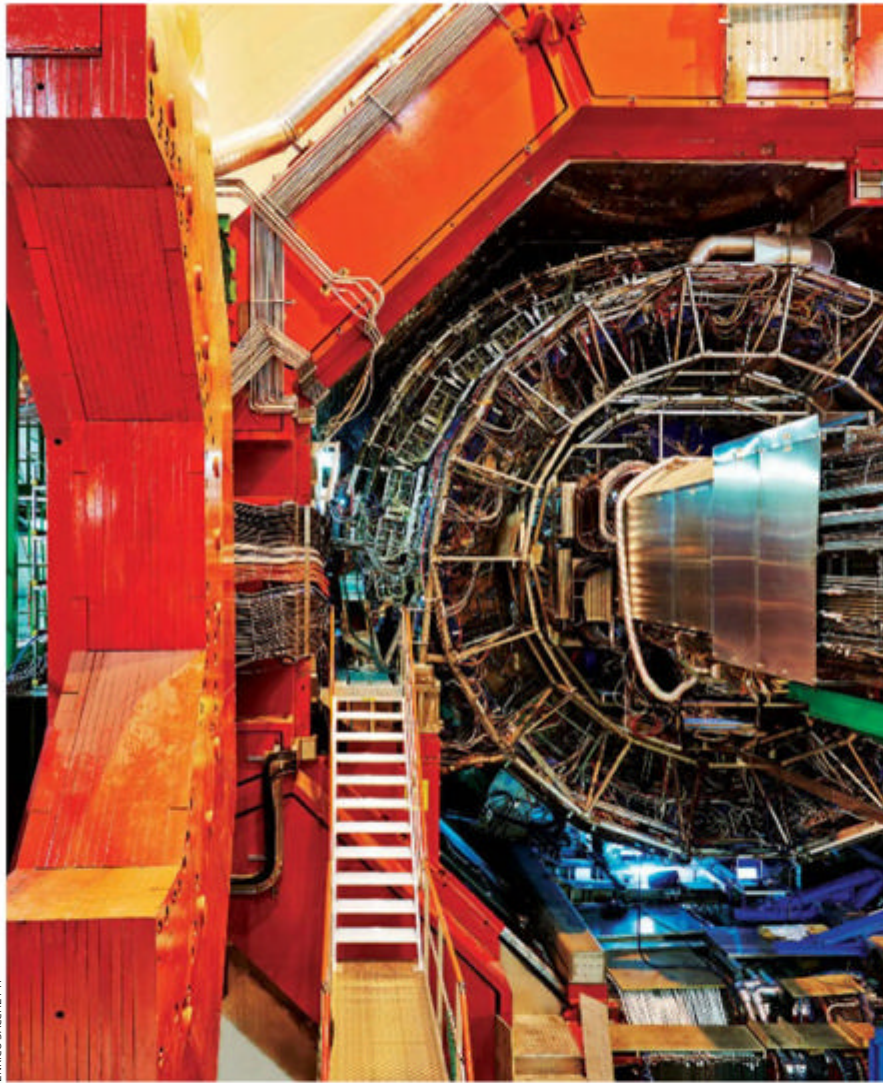
magical, and it is hard to predict how it will occur,” says Andreas Hoecker of ATLAS.

Or if it will occur at all. In a perfectly supersymmetric world, sparticles would have identical masses to their partner particles and would have been seen long ago. Theorists suppose that, rather like the electroweak force, SUSY is “broken” to make the sparticles much heavier. Make them too heavy, however, and they cease to be useful in addressing problems such as the Higgs mass, the nature of dark matter or force unification.

The fact that no sparticles were discovered in the LHC's first run has already limited the breathing space for the simplest, most aesthetically attractive variants of the theory. Like many theorists, Allanach says the next few years of LHC data will decide whether or not he waves goodbye to SUSY. If nothing's found, “it will show that there is something really fundamental at high energy scales that we don't understand,” he says.

While physicists keep a keen eye out for a satisfactory solution to the SUSY conundrum, there remains the vexed question of gravity. The conventional view is that there is no chance of seeing even a hint of unification with this force at the energy scales the LHC can probe. Gravity is so much weaker than the other three forces – by some 40 orders of magnitude – that it can only hope to be unified with them at blistering energies of 10^{16} TeV and above, that correspond almost to the heat of the big bang itself.

But in 1998 theorists proposed a mind-bending alternative. What if our world existed on a “brane” of three spatial dimensions floating in a higher-dimensional space? Then the true strength of gravity might be spread over all these dimensions, leaving it looking strangely diluted from our perspective. If so,



ENRICO SACCHETTI

FASTER, HIGHER, STRONGER

The souped-up LHC will not only be delivering collisions at higher energy, but will also double their rate, amassing a gigabyte of data a second. Further upgrades are planned, meaning that all the data the particle smasher has collected so far would represent just 1 per cent of the total the machine should collect in its full 20-year expedition.

The first job after the restart will be to see if the LHC's two big multipurpose detectors, ATLAS and CMS, are dealing with this huge flow of data properly, by calibrating and testing them on known physics. "Rediscovering" the Higgs boson and making precise measurements of its properties, especially how it

interacts with other particles such as the top quark and the W and Z bosons, are high priorities, says Jim Olsen of CMS.

In the heady days immediately following the Higgs discovery, there were hints that it decayed into pairs of photons at twice the rate expected in the standard model, but the discrepancy melted away once more of the particles had been produced. The consensus now is that the Higgs has a disappointing "plain vanilla" flavour, conforming to every prediction made of it by the standard model. But perhaps more data will once again hint at something more interesting, such as the Higgs being not one particle,

but a composite bundle.

In any case, it is important to investigate how the familiar landscape of the standard model looks from the perspective of the upgraded machine. The particle processes in this landscape will form the expected "background" against which any blips - the signatures of fresh physics - will manifest themselves.

"We need both to confirm that the standard model still holds at higher energy, and to prove that we are able to predict and model the main background to new physics searches," says Olsen. Only then can the hunt for next-generation theories such as supersymmetry begin (see main story).

Stargate: the upgraded LHC could take us closer to the origins of the cosmos and matter

gravity's true strength might be such that the promised land of unification lies at energies much closer to where we are now, perhaps even within the LHC's reach. Then the desert would be no desert, but full of a host of strange objects such as miniature black holes, which the LHC might be able to squeeze into existence by warping and pinching space-time in its collisions. These entities would decay into showers of more familiar particles in highly distinctive patterns.

Even if such things turn out to be too energetic for direct observation, there is a chance that new particles, SUSY or otherwise, might influence the behaviour of things at lower energy scales in ways that are measurable. Some whispers of unexplained effects do lurk in data from the LHC and previous colliders, and these will grow or fade as further collisions amass after the restart. If such a blip grew large enough, that in itself would be a "huge thing", says Allanach. But it wouldn't necessarily tell you what sort of new particle is at play. The trouble with theorists like him, he says, is that they will come up with 20 or more different hypotheses to explain the same blip - all of which work.

For an experimentalist like Hoecker, though, the excitement lies less in proving any "this or that" scenario, but precisely in not knowing what's to come. "There certainly is more room for surprise in the vast space of possible new physics effects than was the case for the Higgs discovery," he says.

So the hope is that the territory about to be explored is a lush forest bristling with particles that give us clues to the nature of the desert - and beyond. If not, then we're stuck, with no indication of what comes next, and no "natural" explanation for why aspects of the standard model landscape look as they do. Faced with such a prospect, physicists are left postulating that only some spooky fine-tuning, some strange coincidence of factors, is responsible. Perhaps our standard model is just one of countless others, in a space in which all possible universes exist. Or perhaps we can move the goalposts and say the answers can be found only with a machine that can reach higher energy scales.

But in the meantime let's saddle up for the upgraded LHC ride, wherever it takes us - so as not to be left back staring longingly at a unreachable kingdom, with a bag containing just the Higgs and a load of unanswered questions. ■

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DAMNISTERS

D A M B U S T E R S

After a 40 year battle, Brazil's grandiose plan to tap the hydropower of the Amazon is coming apart at the seams. Sue Branford and Maurício Torres report

ABOUT 20 men, their arms painted like tortoise shells, are silently hacking away at the forest, opening up a corridor about 4 metres wide. When they have finished, the corridor will stretch for 230 kilometres, encircling the land they call Sawré Muybu. Every so often the men, indigenous Munduruku, erect a sign asserting their ownership of the land in their own language and in Portuguese.

The ancestors of these men used to decapitate their enemies and stick their heads on poles. Although the Munduruku gave up head-hunting long ago, some of the signs feature a painting of a head on a pike. This is their none-too-veiled way of telling the Brazilian government they are determined to defend this tract of Amazon forest that has been theirs for hundreds of years.

The government has other ideas. If it gets its way, work will soon begin on a huge hydroelectric dam close to Sawré Muybu on the Tapajós river, one of the major tributaries of the Amazon. Six other large dams are also on the drawing board for the Tapajós basin (see map, page 37). If the São Luiz do Tapajós dam goes ahead, parts of Sawré Muybu will be flooded.

Dreams of tapping into the immense power of the Amazon began in the 1970s, at a time when little attention was paid to climate and biodiversity. The military dictatorship in

power at the time decided to start with a chain of dams on the Xingu river, another mighty tributary of the Amazon. However, after a lengthy battle with environmentalists and local people, it scaled back its plans to a single dam, albeit a huge one.

Belo Monte finally got the go-ahead in 2011. When it comes on stream in 2019 it will be the third-largest hydroelectric dam in the world. The building site is so big that it seems as if a new Panama Canal is being carved out of the forest. Even if one harbours reservations about the wisdom of this massive undertaking, one can't help but be impressed by the speed and efficiency with which huge layers of rock are blasted into the air and the rubble carted away by a phalanx of giant lorries.

This scene could eventually be replicated across large swathes of the Amazon. According to ecologist Philip Fearnside, a senior researcher at the National Institute for Amazon Research in Manaus, the government has ambitions to turn much of the basin into chains of reservoirs for the production of hydropower. Most of the energy will be used to power big mineral extraction and refining projects in the Amazon itself, particularly aluminium smelting and gold mining.

The issues surrounding the construction of these dams are painfully familiar: habitat destruction, loss of biodiversity and heritage, and the trampling of the rights of vulnerable

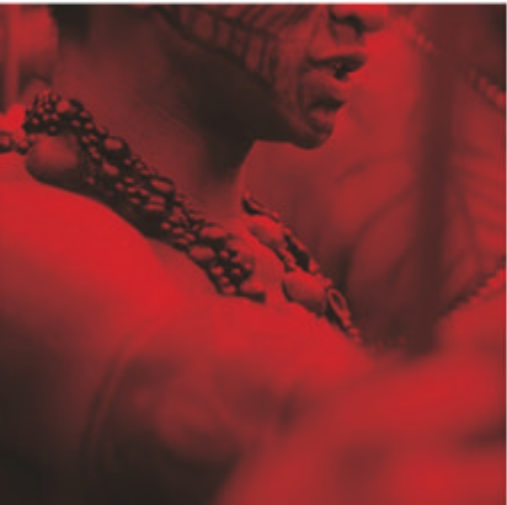
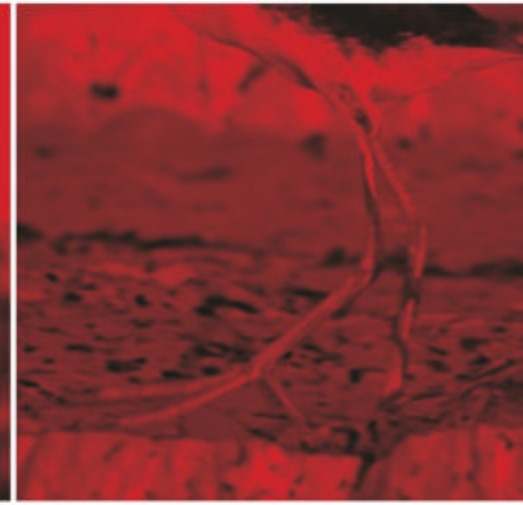
Brazil's hydropower ambitions are creating familiar tensions between development, biodiversity and the rights of indigenous people

people. But the scale on which it could happen adds up to a huge transformation of one of the world's most important natural environments.

No surrender

Before they resorted to direct action to defend their land, the Munduruku tried to go through the proper channels. Brazil is a signatory to the International Labour Organization's Convention 169, under which indigenous and tribal people shouldn't be removed from their land without their free and informed consent. It also states that before licensing a dam, a government must canvass the opinion of all affected groups and only then undertake viability studies. However, in early 2013 the Brazilian government authorised a research company to send in teams of scientists to carry out the viability studies, even though proper consultations with the Munduruku hadn't happened.

Incensed, in June 2013 the Munduruku took three biologists hostage and paraded them, hands bound, in the square of Jacareacanga, a town beside the Tapajós. The government



reacted quickly, promising to carry out the consultations and the biologists were released. However, three weeks later, the government sent the scientists back in under the protection of 250 policemen – still without any proper consultation.

According to reports from the Munduruku and other local people, the police created an atmosphere of intimidation and terror by entering villages unannounced, sometimes arriving by helicopter. In a surreal episode which recalled the days of the dictatorship, a policeman bearing a machine gun tried to bar our way as we approached a group of biologists in a roadside cafe in a remote area of the Tapajós valley.

Brazil's constitution also appears to be on the Munduruku's side, as it bans the permanent removal of indigenous people from their land. But the land claim has to be recognised by the authorities, which can only happen after a report giving the coordinates is officially published by FUNAI, the National Indian Foundation.

FUNAI began mapping Sawré Muybu eight years ago and completed the job in September 2013, but has yet to publish its report. Until that happens, the territory isn't formally recognised as belonging to the Munduruku. The Munduruku believe that the government is deliberately dragging its heels.

We obtained a leaked copy of the report, which shows that FUNAI accepts the Munduruku's claim to the land. The Munduruku are using its coordinates to mark out the boundary of their territory. But it is a long and laborious process.

The Munduruku's troubles have created a dilemma for the scientists carrying out the viability studies, for whom it has become embarrassingly clear that they are involved not in impartial research but in a fait accompli. Talking off the record, some are distraught at the prospect of the overwhelming losses that will be borne by people and ecosystems if the dam goes ahead. Yet they are reluctant to protest or resign, fearing that they will be blacklisted by the government and their career prospects harmed. So they dutifully produce their reports hoping to get the government to rethink its policies. But the government simply cherry-picks the evidence.

A more vigorous response has come from archaeologists. Evidence is being unearthed that the Tapajós basin was occupied by indigenous people for thousands of years before the Portuguese arrived, and archaeologists have been



Clockwise from top left: the Belo Monte dam; pristine rainforest; deforestation; Munduruku protests

contracted to carry out environmental impact studies. This has caused widespread unease. At their meeting in August 2014, the northern branch of the Brazilian Archaeological Society passed a motion stating: "We are gravely concerned by the involvement of archaeologists in a process that relies on the presence of the National Security Force to guarantee the fulfilment of the research. For this reason we are calling on our professional colleagues not to take part in activities related to the environmental licensing of the dams along the Tapajós river."

The concern at the biodiversity loss and the threat to indigenous people is exacerbated by a growing awareness that the drive to harness the power of the rivers may, in the long term, be futile. São Paulo, the industrial heartland of Brazil, is in the grip of the worst drought in living memory. The clouds from the Amazon that make the basin itself so wet and also deliver rain to the south of the country –



dubbed "flying rivers" by one Brazilian scientist – have failed to materialise.

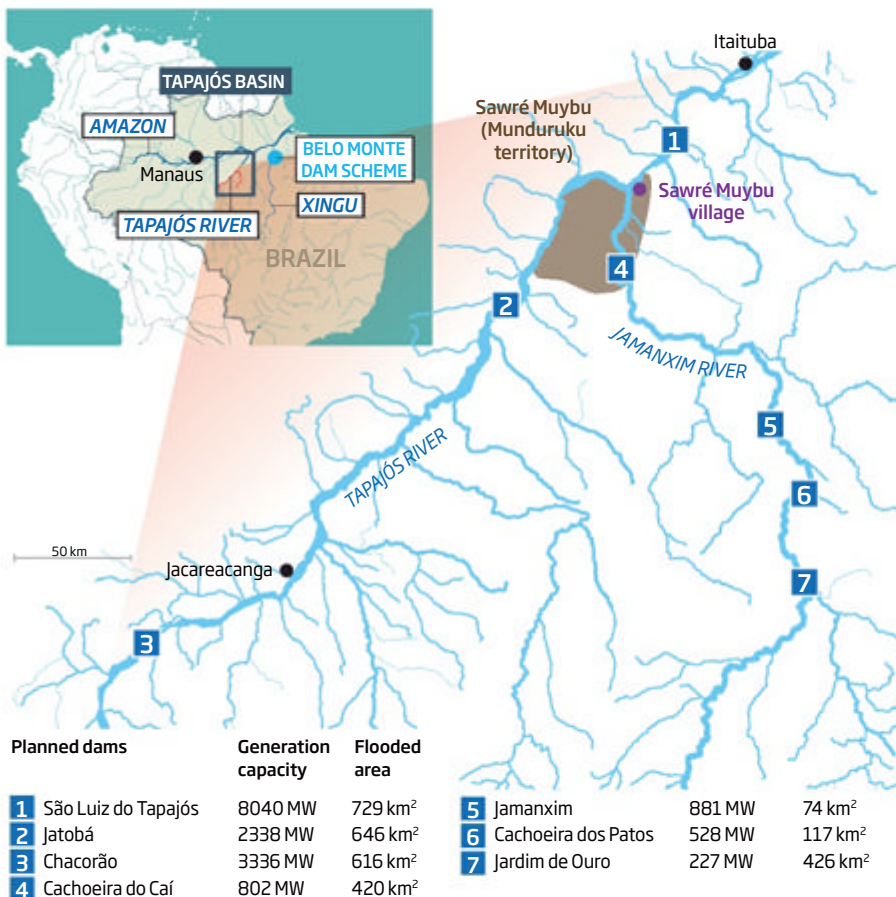
While this may be a result of natural climate variability, Antonio Nobre, a senior researcher at Brazil's National Institute for Space Research in São José dos Campos, says that the disruption is linked to deforestation. Recent research has shown that Amazon vegetation, particularly large trees, play a central role in maintaining the hydrological cycle. "In a single day a large tree in the rainforest can pump over 1000 litres of moisture from the soil into the atmosphere. If this is scaled up for the whole forest, it means the Amazon forest transpires 20 billion tonnes of water a day," he says. Cut down the forest and you destroy the flying rivers.

According to official satellite data, 22 per cent of the forest has been felled. But this is an underestimate as it fails to account for selective logging, which the satellite images don't detect. After several years of marked declines in forest clearance, which won Brazil international plaudits, the level of deforestation has risen again.

It seems probable that continued forest destruction will sooner or later trigger a

Watery grave

The Brazilian government wants to build seven large hydroelectric power stations on the Tapajós river and its tributary, the Jamanxim, flooding parts of the indigenous Munduruku's territory



dramatic transformation of the Amazon. The tipping point was spelled out in 2013 by the Brazilian Panel on Climate Change: “Modelling studies have suggested that, if deforestation reaches 40 per cent in the region, drastic changes will likely occur in the hydrological cycle, with a 40 per cent reduction in rainfall during the months from July to November.”

Even scientists with a less alarmist outlook than Nobre believe that, if deforestation continues, the viability of the large dams may be compromised. Until recently most scientists thought that cutting down trees near dams increased the amount of water flowing into them. But a recent study by the Amazon Environmental Research Institute in San Francisco, California, came to a very different conclusion. It found that by 2050, when on present trends at least 40 per cent of Brazil’s Amazon forest will be gone, there will be a significant decline in river flows and energy generation (PNAS, vol 110, p 9601). This would make the reliability of the dams as an energy source highly questionable.

Another difficulty is that big development projects always provoke an unruly influx of

“Big projects always cause forest felling and there is no sign of that ending”

illegal loggers, land thieves, cattle ranchers and slash-and-burn farmers, who exacerbate the deforestation. The government promises it will be different with São Luiz do Tapajós, through the use of river platforms similar to North Sea oil rigs to make it possible to bring people in using helicopters rather than roads.

But Juan Doblas of the non-profit Social-Environmental Institute in Altamira points out a flaw: “Yes, when a dam is up and running, you can bring workers in by helicopter. But the main environmental damage is done during the building of the dam, when thousands of labourers are needed. You can’t bring in this volume by helicopter. Big projects always cause forest felling and there is no sign of that ending.”

A radical solution would be to see if Brazil could do without dams on the Amazon. Nobre says that much could be done to save energy. “Brazil wastes 55 per cent of public street

lighting because the lenses spread the beam wider than is necessary. By refocusing the light we would save as much energy as Belo Monte will generate,” he says. Another source of waste is electric showers. “If we were to install solar water heaters, which would not be difficult with the amount of sunshine we get, there would be no need for further hydroelectric dams in the Amazon.”

Along with growing doubts from scientists, another factor is creating the perception that the authorities’ love affair with Amazon hydropower may be waning. Historically, one of the biggest drivers of dam-building has been a cosy relationship between big engineering companies and their political allies. “Energy planning in Brazil is not treated as a strategic issue but as a source of money for engineering companies and politicians,” says Felício Pontes, prosecutor for the Federal Public Ministry in Pará.

But many of the companies are now caught up in a massive corruption scandal involving bribery and money laundering by the state-owned oil company, Petrobrás. Investigators are examining the contracts for the Belo Monte dam, and a leading executive of one of the companies, Camargo Corrêa, which has been funding viability studies for the São Luiz do Tapajós dam, has been arrested.

As a result, there is no longer the same impetus to push ahead with the dams. Until recently, the government was planning to generate electricity from all the main tributaries of the Amazon east of the city of Manaus. But in a leaked copy of its latest 10-year energy plan, obtained by the *O Estado de S. Paulo* newspaper, all dams except São Luiz do Tapajós have been removed. Even this is no longer on the list of priority projects to be built over the next five years. If confirmed, this amounts to a major rethink of Brazil’s energy plans, and a possible reprieve for the Amazon.

Meanwhile, the Munduruku fight on. Emboldened by a judicial decision that “full, free and prior consultations” must be carried out, a delegation of 30 made the five-day bus journey to Brasília at the end of January to present their demands – the central one being the cancellation of the dam.

They are still a long way from achieving victory. But after decades of bitter struggle, the battle for the Amazon finally seems to be going their way. ■

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Your brain on migraine

Migraines cause profound changes to the way people experience the world every day. Helen Phillips reports

WELL a very, very heavy ah heavy duit burtation tonight. We had a very deres dereson. But let's go ahead tarish tasen losh lobitt behend dupet". News reporter Serene Branson's unintelligible live TV commentary on the 53rd Grammy awards ceremony in 2011 made her an overnight internet sensation. As the paramedics attended, the worry was that she'd suffered a stroke live on air. Less-kind pundits blamed drugs, stage fright, or alcohol. In interviews shortly after, she revealed she'd been having a migraine.

I too have experienced this type of migraine "aura", though thankfully rather less publicly. In mid-sentence, with absolutely no warning, I began talking drivel. I couldn't find the right words, but I also couldn't stop myself garbling nonsensical phrases with similar starting sounds or patterns to the words I sought. I was mortified. A few minutes later I developed a

steadily expanding blind spot edged with a semicircle of dancing black-and-white zigzags. Several days later came the most intense headache imaginable. I was 19.

Migraine is often thought of as an occasional severe headache, sometimes accompanied by strange visual effects and nausea. There's a feeling it isn't really serious because once the headache is over the person goes back to normal. But these bizarre and disturbing aura symptoms alone should tell us there's far more to migraine than meets the eye. Over the past decade, research has been building a picture of a condition which is much more serious than many give it credit for. It shows that migraine is caused by real structural and functional differences in the brain, and that people who experience migraines feel, see, touch, hear and respond to the world differently all the time, not just during an attack. Perhaps more worrying,

the disorder, and the brain changes that accompany it, seem to be progressive, getting worse with each attack. "Migraine is a more serious condition than people have thought," says David Borsook of Harvard Medical School in Boston. "These repetitive strikes change brain networks, and we are just beginning to understand those."

More than 37 million people in the US alone experience migraine, although an estimated 50 per cent of sufferers, also known as migraineurs, go undiagnosed. Given these recent findings then, it's time to rethink how we tackle, diagnose and treat the condition. "We need to stop calling migraine a vascular disease or a pain condition," says migraine expert Peter Goadsby, who splits his time between King's College London and the University of California, San Francisco. "It is a neurological disorder."

The effects of migraine have been



IF YOU GET THEM...

Although migraine is a result of abnormal brain activity, the causes are still unclear. Around 70 per cent of people who report migraines have a family history of the condition, but because of misdiagnosis, family history may remain hidden.

Migraine attacks usually involve intense, one-sided throbbing head pain. They are also generally accompanied by other symptoms, ranging from nausea and sickness to sensitivity to light, sounds and smells. There may be nasal congestion, tears and sweating. Sometimes there is tingling in limbs, neck pain, even one-sided paralysis and slurred speech, so occasionally it looks almost like a stroke. And around 20 per cent of people who suffer from migraines get the strange visual or auditory hallucinations known as aura. Because the symptoms of migraine are so broad, it is often misunderstood and misdiagnosed.

So if you think you might suffer from migraine, seek professional advice and get a proper diagnosis. Find out what kind of lifestyle changes and medications are most appropriate for your symptoms. Do not just tough it out, as that can make things worse in the long run. Self-medication with over-the-counter painkillers can even prolong the pain. Taking painkillers can lead to rebound, where the symptoms return as the drugs wear off, leading to a cycle of often worsening symptoms.

Do try to keep a good routine, sleep well, stay hydrated and try to eat "clean". If nothing else it might help you to identify patterns and triggers for your attacks. A migraine diary will help, and there are also online diaries and apps which can help find links you might not have considered.

The brain attends to all sorts of things it should be ignoring

documented for centuries, but only now are brain imaging technologies allowing us to see the big picture. Most media attention so far has focused on reports that MRI brain scans of some people with migraine show tiny areas of damage, which show up as small bright spots on the image. In 2004, Mark Kruit from Leiden University Medical Center in the Netherlands and his colleagues scanned the brains of around 300 people with migraine and found that they were more likely to have such bright spots than carefully matched controls. Some of the spots, mostly in the cerebellum, related to changes in the deep white matter, which is the insulating sheath that allows nerve fibres to send electrical signals efficiently and is now also known to be important in learning and memory.

Worryingly, other spots closely resembled the kinds of damage you would expect to see in the brain of someone who'd had a stroke. The incidence of these so-called stroke-like lesions was not high, but it was statistically significant – they were apparent in around 8 per cent of cases of migraine with aura compared with 5 per cent of controls.

Stroke-like damage

As if the words "stroke-like lesions" weren't worrying enough, no one is quite sure what these spots of damage on the brain are, or what they mean. We already know that having migraines puts people at greater risk of stroke – especially those with aura and cardiovascular risk factors such as blood pressure problems, who smoke or are obese,

and women taking certain oral contraceptives. "Because the blood flow to parts of the brain related to the aura first increases then decreases, it is possible that the changes are related to small strokes," says Richard Lipton of the Albert Einstein College of Medicine in New York, who recently published a detailed review of structural brain changes in migraine. But as both he and Kruit's team are quick to point out, the spots don't appear to cause symptoms, or make migraine worse.

To find out what's really going on, these changes needed to be monitored. Do regular migraines cause more areas of stroke-like damage? And to what effect? Kruit and his team rescanned most of their volunteers nine years later. Interestingly they found the number of spots had slightly increased over time in women with migraine, but not in men, but they didn't correlate with migraine frequency, severity, or treatment. Neither did the spots seem to have any bearing on cognitive functions like memory or attention. Another long-term study in France found no link between migraines and cognitive decline, all the way to age 80.

That is good news given that even silent strokes – where damage to the brain can be seen on scans without there being any clinical symptoms – have been shown to be a risk factor for cognitive decline and dementia later on.

According to Kruit, the spots may relate to having the "disease" of migraine, rather than being caused by successive attacks. And it

"Even normal touch can feel painful to people who have frequent migraines"

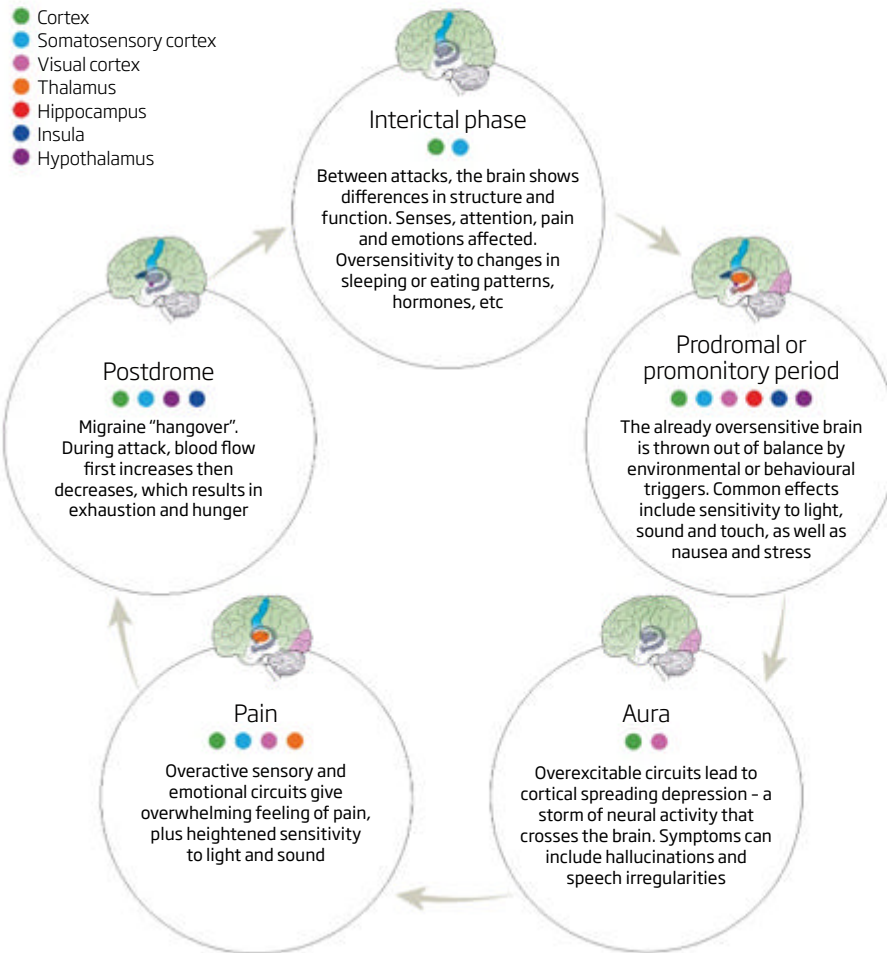
doesn't look like the brains of people with migraine age faster, says Lipton.

So the jury is still out on the significance of the stroke-like lesions in migraine. However, there are other, less-talked-about structural changes in the brain which may be much more important. These differences relate directly to the changing and increasing severity of migraine symptoms over time. Several groups have now described changes in the thickness or volume of various brain areas in people with migraine, and they seem to underlie the sensory, emotional and sex differences in people's experience of the condition.

In one study from 2007, Nouchine Hadjikhani and her team at Harvard Medical School found thickening of a region known as the somatosensory cortex, which maps our

Cycle of sensitivity

The brains of people who experience migraine work differently overall, not just during an attack. Studies are starting to reveal which circuits may play a role in the various stages of migraine, although the picture is still developing



sense of touch in different parts of the body. They found the most significant changes in the region that relates to the head and face. "Migraine has always been considered as an episodic problem," says Hadjikhani. "But if you have a series of episodes of pain in the face area, it increases cortical thickness." If people have frequent migraines, they often develop a condition called allodynia, where even normal touch can feel painful. Estimates vary, but this condition is thought to affect at least a quarter of migraineurs. "It's an important finding," she says. "Migraine could have long-term consequences."

Her group has also identified thickening in the visual cortex, which makes sense when you consider how frequently migraine attacks are accompanied by visual disturbances. One

of the physiological features of a migraine attack is a storm of neural activity called cortical spreading depression that passes in a wave across the brain's surface.

Hadjikhani's group was first to record this epilepsy-like activity in a brain scanner during migraine aura, in a visual region that responds to flickering motion. The study confirmed a long-suspected link between spreading depression and the aura that often precedes migraine pain. "People with migraine often have a history of motion sickness, sensitivity to stripes or certain visual stimuli," says Hadjikhani. "And we found increased cortical thickness in these visual areas."

She admits they don't yet know whether the changes cause the areas to produce these storm waves or are a result of them. Indeed

TRIGGER TROUBLE

One unique feature of migraine is the way it appears to be "triggered" by something environmental. Common triggers are said to include red wine, chocolate, flashing lights, hormonal changes, sleep disruption, and stress. Doctors advise patients to try to identify their own triggers by keeping a migraine diary, and to make changes to their lifestyle and diet. But recent studies show that the story is more complex than first thought.

For a start, the things that get reported as triggers may not always be to blame. In one recent study on people who believed their migraines were triggered by flashing lights, the researchers failed to trigger a single attack in the lab using all manner of annoying lighting and strobes. Instead, it could be that the trigger itself does not cause the attack, but that people are more susceptible to these stimuli once a migraine is under way, and are therefore more likely to notice them.

During the prodrome stage of an attack (see diagram, left) people are more sensitive to stimuli such as light and noise, but don't always realise that their attack has started. It's possible that sleep may be disrupted by the attack, that things feel more stressful or that a stimulus like bright lighting becomes more troublesome. These things might then be blamed for the attack that was already in progress.

Stress let-down, the feeling of relief after a period of stress, has also been found to be one of the most common triggers. People often report migraine at the weekend or after a big exam or work event. But even this might actually be due to change of routine - a lie-in, say, or a change in diet or caffeine intake.

other work suggests that spreading depression may occur all over the brain, often unnoticed, and may even happen in healthy brains.

So aura may be the result of a person's brain being more sensitive to spreading depression.

The list of structural changes, often in the form of thickening, has been growing in recent years, so that now there is barely a region of the migraine brain that has been found to be unchanged. This list includes sensory and emotion areas, and the hippocampus - which is involved in autobiographical memory and navigation - along with reward networks, frontal areas involved in planning, cognition and voluntary actions and, not surprisingly, regions that involve pain. "We have to look at [the possibility] that the whole brain is altered," says Borsook, with different

RELIEF AHEAD

As we learn more about the underlying neural mechanisms of migraine, new treatments are emerging. Brain stimulation will be huge in the next five years, says Peter Goadsby of King's College London.

Transcranial magnetic stimulation (TMS) and other techniques that deliver small electrical currents through electrodes on the forehead are already proving effective in some cases of migraine, as well as for chronic pain conditions and depression.

These treatments seem to work by steadily altering and normalising oversensitive brain circuits, though at

present it's not clear how. One big advantage is that they are well tolerated compared with other therapies, including drugs and botox - which is approved for migraine treatment by the US Food and Drug Administration.

TMS and the like also have scope to treat people who have become insensitive to migraine drugs, those who experience rebound symptoms (see "If you get them...", page 40), and women who are pregnant or breastfeeding.

A huge change in drug treatment is on the horizon too. The first group of medicines to be developed specifically

for treating migraine is just a few years from the pharmacy. These block a molecule called calcitonin gene-related peptide, or CGRP. Goadsby first found CGRP in the blood of people experiencing a migraine attack nearly 30 years ago.

Now, a handful of drugs that interrupt CGRP receptors are being tested for episodic migraine, and monoclonal antibodies, which bind to the receptors for longer, are being tested for people with chronic migraine. Several candidate drugs are in phase II trials. These could be ideal for tackling the long-term effects of migraine on the brain.

structures being more or less involved. "The whole migraine brain is very excitable," he adds, "much more excitable than in healthy subjects." His suspicion is that repeated attacks make it that way. Indeed, Hadjikhani's team also found microscopic structural differences in the thalamus, an area that transmits sensory information to the cortex and controls its excitability. "It was as though small pathways had become highways to transmit the pain, says Hadjikhani. "Using the system repetitively makes it work more efficiently."

But it is perhaps functional changes in the hypothalamus that have caused most excitement in the medical world. The hypothalamus is vital for controlling internal body states - things such as sleep and waking cycles, metabolic balance, feeding behaviour, stress, and hormone cycles - all of which are linked to migraine attacks. Migraineurs will recognise many of the symptoms controlled by circuits around the hypothalamus: nausea and vomiting, nasal congestion, watering eyes, excessive urination, thirst and hunger, cravings, yawning and tiredness. "The idea that the hypothalamus is a critical centre in migraine is not new," says Borsook, "but we now know that there are functional differences in how the hypothalamus interacts with other brain areas in migraine."

Functional MRI scans enable researchers to look at how closely correlated the activity

of different brain areas is. In people who get migraines, such scans revealed raised "functional connectivity" in the circuits between the hypothalamus and areas that control automatic regulation of our body states. These areas normally respond to all sorts of stressors including cold, hunger and exercise. This makes the circuits much more sensitive. Think of the level of sensitivity as a threshold. If you haven't slept well or eaten properly, your oversensitivity to dysfunctional activation

"A startling possibility is that infant colic is an early form of migraine"

allows your brain to overreact, and go into a full-blown migraine attack. What's more, says Borsook, this sensitivity seems to increase during an attack, and with more severe or more frequent migraines.

A better grasp of these structural and functional changes may also be the key to understanding one of the most curious aspects of migraine - that it affects around three times as many women as men. Nasim Maleki, also at Harvard Medical School, and colleagues including Borsook, found that the biggest differences between male and female migraineurs were in two brain regions. One

was the precuneus, an area that is likely involved in self-awareness, which fits with my own experience of migraine - I always describe the pain as coming from the part of my brain where I feel "I" am when I close my eyes.

The other is the insula, specifically the posterior insula, which is involved in sensory processing and control of our automatic body functions. The insula is an intriguing part of the emotional brain, involved in several important functions including sensation, autonomic regulation, understanding our internal state (interoception), and "salience", in other words judging what is important right now. Both areas were thicker in women with migraine than in men with the condition.

When it comes to functional imaging of male and female brains, Maleki's team found that migraine in women seems to involve more activity in emotion circuits than in men. The pain may be a more emotional experience for women, and anecdotally many do report feeling intense mood swings before and after migraine strikes. There is also a strong association between depression and migraine. Female sex hormones may well underlie the differences, somehow making the circuits more sensitive to change with repeated attacks, but the mechanism is not clear.

Borsook is now studying how migraine progresses in children as they enter and pass through puberty, and has found stark differences between boys and girls. "There's



no question that when boys go through puberty there's a good chance their headaches will resolve," he says, "and in girls, a good chance their headaches will get worse."

Work with children is adding weight to the idea that migraine is a progressive brain disease, which may appear in different ways at different stages of life, beginning with some kind of genetic susceptibility. One startling suggestion is that infant colic, the uncontrolled crying and fussiness often blamed on sensitive stomachs or reflux, may be an early form of migraine. Goadsby and colleagues have looked at the prevalence of migraine in mothers of babies with colic, and early indications are that it is more prevalent in the family of colicky babies. In a study of 154 mothers whose babies were having a routine two-month check-up, the migraine sufferers were 2.6 times as likely to have a baby with colic. It is possible that a baby with a tendency to migraine may not cope well with the barrage of sensory information they experience as their nervous system starts to mature, says Goadsby, and the distress response could be what we call colic.

So what are we to make of all this research? The brain of a person with migraine is emerging as oversensitive, and increasingly so with successive attacks. Perhaps not surprisingly, researchers are finding corresponding differences in brain function, even between attacks. Marla Mickleborough,

a vision specialist at the University of Saskatchewan in Saskatoon, Canada, found heightened sensitivity to visual stimuli in the supposedly "normal" period between attacks. People with migraine are less able to tolerate staring at a bare light bulb, for example.

Her findings draw on previous work showing that the brain's response doesn't "habituate" as it would normally do. Usually the brain comes to see something repeating over and over again as unimportant, but in people with migraine the response doesn't

TYPES OF MIGRAINE

Migraine with aura Warning signs before the migraine begins, such as visual distortions

Migraine without aura Migraine occurs without warning signs

Silent migraine Aura or other migraine symptoms are experienced, but no headache

Chronic migraine Experienced at least 15 days in every month

Episodic migraine Occurs occasionally

Abdominal migraine Usually occurs in children. Recurring attacks of abdominal pain

Menstrual migraine A specific condition where the attacks occur around menstruation and at no other time

Hemiplegic migraine Attacks include paralysis or weakness on one side of the body

diminish over time. Suspecting that the problem was related to attention, Mickleborough recently tested visual attention in migraineurs. "They seem to be attending to things they should be ignoring," she says: "They find it hard to concentrate." It matches anecdotal reports and my own experience that especially in the day or two before an attack, I find myself easily distractable and unable to settle at my computer. I can't tolerate flickering adverts, or ignore TV screens and am much more distracted by music or talking.

Hard to ignore

Mickleborough also finds that migraineurs do not perform well in tests of negativity bias – a well-studied psychological phenomenon in which we pay more attention to stimuli we don't like, perhaps because they have a higher chance of being important and threatening. The fact that migraineurs don't do this could add to the general feeling of being distracted by numerous stimuli all at once and finding it harder to focus on the right thing.

The idea that our brains are different, and growing ever more so with every attack, is deeply worrying for those of us who experience migraine. It's a wake-up call for doctors to treat the condition more aggressively, and to find out more about each individual's particular triggers (see "Trigger trouble", page 41) so as to stop attacks from happening, rather than let people suffer through each one while it sensitises the brain.

But there is a silver lining. Despite talking about migraine as a progressive neurological disorder, these structural changes should not be likened to dementia, Alzheimer's disease or ageing, where brain tissue is lost or damaged irreparably. "That's the wrong way to look at it," says Borsook. In migraine, the brain is compensating, he says. "Even if there's a genetic predisposition, it is the disease itself that is driving networks to an altered state." That means that treatments that reduce the frequency or severity of migraine will probably reverse some of the structural changes too. Lipton agrees.

"Headache begets headache," he says. Treatment used to be about reducing the immediate pain, he says, but now it seems that finding good treatments for migraines may have much longer-term benefits. ■

Helen Phillips is a consultant for *New Scientist* and author of *Emotion: Pleasure and pain in the brain* (OUP, 2014)

An unexpected discovery has created a laser that can manipulate your vision. And you won't even know you're the target. David Hambling reports

Blinded by the heat



IT BEGINS without warning. You are driving fast on the highway and your vision starts to blur. As vehicles around you become hazy and the road ahead fades, you lose control. Even if you survive the impending crash, no one may ever find the cause, because you have been targeted by a weapon that leaves no trace.

Such a device already exists. Tagged by its developers as non-lethal, it is a laser designed for use by security services or on the battlefield. It sends out an invisible beam that temporarily blurs vision, apparently without damaging the eye. The hope is that it could be used to temporarily blind potential snipers or disable terrorists before they act.

But the story is not quite so clear-cut. Would such a laser be less dangerous than conventional alternatives, such as laser dazzlers or tasers? After all, with a driver or pilot in the firing line, it could cause fatalities. What's more, there would be no evidence of the cause. Aviation authorities are already trying to prevent people from shining powerful laser pointers at aircraft, fearing they will blind pilots. Such pointers produce visible light, so at least there is a chance of deterring or catching the culprits. But it is a different story with this weapon. In the wrong hands, it would cause chaos.

Lasers concentrate energy into intense light beams, so it is hardly surprising that people have tried to turn them into weapons. In the 1980s, for example, the UK Royal Navy developed a system to blind attacking pilots, and the US created lasers to defend aircraft, helicopters and vehicles. Laser weapons capable of blinding people were outlawed by an amendment to the Geneva Conventions in 1996, after a successful campaign.

Yet lasers that cause temporary vision loss are still permitted. Laser dazzlers or "ocular disruptors" used to send signals or as dazzlers

are widely used. The Glare system, for example, is a flashlight-sized device that was fielded by the US military in Iraq to signal to drivers as they approached checkpoints. And the US police and coastguard service received the go-ahead to use laser dazzlers in 2012.

Although designed to be safe, these devices can still damage eyes, particularly when used at close range. To help prevent this, dazzlers have a minimum safe distance at which they should be operated – and some even switch off automatically when a target is too close. Despite this, lasers damaged the eyes of some US soldiers in Iraq. It is not clear how many civilians have been affected.

So if lasers are going to be used in these ways, there's a need to make improvements. Researchers have tested strobing lights, and combinations of light and sound that can disorientate, even at low light intensities. Then in 2009, researchers from defence technology company Northrop Grumman and the Air Force Research Laboratory at Brooks City Base in Texas came across a promising lead: they noted that mammal eyes are particularly resistant to damage by infrared laser light at a wavelength of 1320 nanometres. In tests it took at least 50 times more power at this wavelength to damage the retina than at shorter wavelengths.

Further studies revealed why: although our eyes can't detect light at around 1300 nanometres, the infrared is absorbed by the structures of the eye – the lens, cornea and the fluid inside the eyeball – and they heat up. This changes the eye's refractive index, altering the way light travels through it. The effect, known as thermal lensing, prevents the eye focusing the light onto the retina, so there is no tight pinpoint of light to cause damage.

Thermal lensing seems to open the door to all kinds of remarkable effects. In tests with

low-power infrared beams, the air force team, working with researchers at the University of Texas at Austin, found they could blur the eyesight of volunteers, making it appear that they were gazing through a heat haze. In another study, published in 2014, the team reported reducing the eye's ability to focus by 2 dioptres, equivalent to inducing moderate short-sightedness. With more powerful beams, they found they could entirely block out parts of their volunteers' vision. All these effects disappeared as soon as the laser was turned off and didn't heat the eye enough to cause damage, says Benjamin Rockwell, one of the team at the Air Force Research Lab. With much the same range as a conventional laser, it seems to offer a less-dangerous alternative to visible-light dazzlers, he says: "a unique way to temporarily challenge someone's vision".

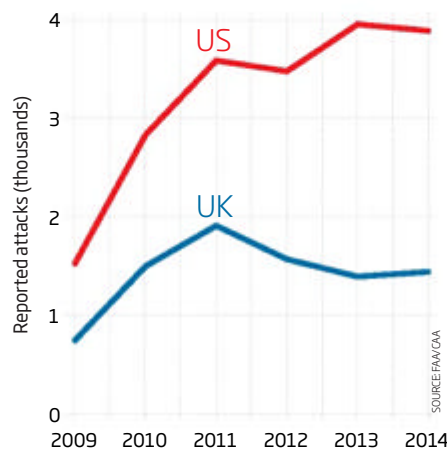
Any device that manipulates eyesight could make a powerful weapon. It could certainly stop a sniper, or disable a driver approaching a checkpoint. But there are still possible problems, says Jürgen Altmann, a physicist at the Technical University of Dortmund in Germany. "Whenever one manipulates the human eye, there are obvious safety issues," he says. We don't fully understand thermal lensing yet, he says, so more research is needed on the effect and its implications. There is a big difference between controlled tests in a lab and the much broader beams used during actual operations, he says.

Stephen Coleman from the University of New South Wales in Canberra, Australia, who studies military ethics, warns that using any kind of invisible light is inherently more dangerous: "With visible dazzlers, exposure is limited because people look away."

Visible lasers have been aimed at the police during riots and public protests

One in the eye

Laser pen attacks on the eyes of pilots during flights have risen dramatically over recent years in many countries including the US and UK. Would new, more dangerous technology follow a similar trend?



But with an infrared laser, there's no such limitation – people might blink more, but not turn away. Those using such devices may also ignore limits because they can't see their targets react. "Safety limits might be exceeded because there's no visible effect for the user: 'I've been using it for 5 seconds and nothing is happening, I'll keep using it,'" says Coleman. And anyway, he adds, the device is simply not suitable for police use. "Weapons like pepper spray, tasers, and even firearms, disable suspects so they can be taken into custody. This blurs vision. The range of circumstances in which it could be used is very limited."

Combining the infrared beam with a visible laser could get around some of these problems, Rockwell believes. This pairing could disrupt vision more effectively in daylight, at lower energy levels, he suggests.

"There may be an optimal configuration which allows higher exposures before a dangerous level is reached."

On the other hand, this combination could also increase the potential for blinding in some people, Rockwell and his colleagues say. The eyes of people who are long- or short-sighted are unable to focus light on the retina, and thermal lensing might provide exactly the change their eyes need for perfect focusing. The device could temporarily improve their vision and so cause serious eye damage.

Close to market

It might be some time before the military turns infrared lasers into practical weapons, but others may not take so long. Last year, security equipment provider Shield Defense Systems of Reno, Nevada, announced a "retinal obfuscation" device called Z-RO. The company's website claims it blocks vision for 10 to 15 minutes, but will not damage the retina or cornea "as these are not targeted to achieve the visual obfuscation effect". Although the company won't discuss this technology, its details appear to match the US air force's thermal lensing laser. Shield claims Z-RO is in the manufacturing stage, and should be available soon.

Whatever happens, lasers operating at a wavelength of 1320 nanometres are already used in research labs, for medical treatments such as scar removal and in optical communications systems. Shrinking these lasers to weapon-size portability remains a challenge, but laser technology is advancing rapidly, so this may not take long. And that's when the real problems could begin.

Some of the challenges arising from small, portable lasers are already evident. According to the US Federal Aviation Authority, in the US alone there are 11 incidents every day in which pilots are targeted with small but powerful laser pointers (see chart, above). This has caused eye injuries, but no crashes so far. Bus, truck and train drivers have also been targeted. Some incidents have led to accidents.

Authorities have a chance of tracing people who use visible lasers. That would be much more difficult if they were wielding a thermal laser. "There would be much potential for misuse by criminals and irresponsible people, against car drivers, pilots or for robbery," says Altmann. Even the victim might be unaware of what was happening. "Only a small percentage of those exposed have reported any sensation of heating," says Rockwell. "Except for the visual effect, most are unaware of the exposure."

It's a sobering thought. The truth is, if there's one thing worse than knowing you're the target, it's not knowing. ■

David Hambling is a writer based in London, UK



TODD DARLING/POLARIS/EVINE

From grey matter to you

Split brains told us a lot, but the mystery of mind eludes us still, finds **Anil Ananthaswamy**

Tales from Both Sides of the Brain: A life in neuroscience by Michael S. Gazzaniga, HarperCollins, \$28.99
The Future of the Brain: Essays by the world's leading neuroscientists edited by Gary Marcus and Jeremy Freeman, Princeton University Press, \$24.95/£16.95

“HOW on earth does the brain enable mind?” This line from the preface to *Tales from Both Sides of the Brain* by neuroscientist Michael Gazzaniga serves as the overarching question for his latest book. And it’s also a question that permeates *The Future of the Brain*, a collection of essays edited by psychologist Gary Marcus and neuroscientist Jeremy Freeman.

But what a difference in the techniques the authors use to explore the answers. Gazzaniga’s book is a deep dive into his own personal and professional life and, as such, it’s filled with anecdotes that reveal not just the science but also the scientists, their passions, foibles and follies.

His journey begins in the early 1960s as a graduate student at the California Institute of Technology, where he worked with people with split brains. His advisor was Roger Sperry, the neuroscientist who pioneered the study of animals whose brain hemispheres had been surgically separated.

It was also a time when neurosurgeons were beginning to treat severe drug-resistant epilepsy by cutting the corpus callosum, the bundle of nerve fibres that connects the brain’s two halves, to stop the spread of epilepsy’s electrical storm. Sperry got Gazzaniga studying someone who had undergone this procedure – setting him on course for a life of scientific discovery.



PHILIPPE OPPARELLI/TENDANCE FLOUE

The book is an intimate look at a simpler time, when deep insights could be gleaned by designing deceptively simple yet elegant experiments, such as showing objects to the left or right visual fields of people with split brains and analysing their responses.

Such work led Gazzaniga to his theory that the left brain is an “interpreter”, trying to make logical sense of our experiences – even when information is only perceived by the right brain and isn’t reaching the left. “Though the left hemisphere had no clue, it would not be satisfied to state it did not know. It would guess, prevaricate, rationalize, look for

a cause and effect, but it would always come up with an answer that fit the circumstances,” writes Gazzaniga. Above all, he says, it is “the special device... that gives our actions one narrative and the sense that we have but one mind”.

Whether you like reading about how such insights happen or care more about the people who have them, Gazzaniga amply delivers. Personally, I enjoyed interludes such as the Caltech party where Richard Feynman offered himself as a subject for split-brain surgery, if Gazzaniga guaranteed he would still be able to do physics. Gazzaniga writes that “Feynman stuck out both left and right hand to shake on the deal!”

There’s no such levity in *The Future of the Brain*, a collection of accessible but academically inclined essays charting where

Left brain, right brain: the differences tell us about the whole

neuroscience is headed. Among the contributors are Ned Block, George Church, Christof Koch, as well as May-Britt Moser and Edvard Moser – 2014 Nobelists.

Many of the essays point to a future of high-resolution maps or brain atlases, showing genes, connections or brain activity, and taking us well beyond today’s fMRI and PET scans. For example, techniques that tag individual neurons with any one of a hundred fluorescent proteins, or make brains optically transparent will transform imaging.

The technologies will generate lots of data, and neuroscientists will need large-scale simulations and brain models to make sense of it. Editors Marcus and Freeman

“Feynman offered himself up for split-brain surgery if Gazzaniga guaranteed he’d still be able to do physics”

say that we had better get used to seeing the brain as an organ that carries out computations – a notion that is often resisted. They write that “nerve cells exist to compute; the real trick is to figure out what they are computing”.

And as we figure that out, will neural interfaces be far behind? The most far-reaching technology imagined in the essays is “neural dust” – specks of silicon coupled to piezoelectric crystals that stimulate and record activity from neurons. These devices would be sprinkled throughout the brain, communicating to a receiver on the skull via ultrasound.

They sound scary. I would have welcomed more on the ethics of such technologies, building on bioethicist Arthur Caplan’s argument that mapping the brain must be about more than just gathering information and discussing how to use it. Caplan writes: “Scientists must also debunk hype, allay groundless fears, and anticipate... ways in which efforts may be made to exploit or dupe the public in the name of knowledge derived from brain maps, studies, and scans.”

It’s a welcome cautionary note, as is a caveat in Block’s essay, advocating clarity about the relationship between brain activity and psychological experience. He writes that “massive quantities of data alone cannot produce theoretical breakthroughs in understanding the mind at a psychological level”.

Koch and Marcus end with a futuristic essay, looking back from 2064 and hoping for a solution by then to the “hard problem” of how subjective feelings, and consciousness itself, emerge from a physical brain. Maybe in that future a neuroscientist will also write a popular account spanning the momentous 50 years that answered Gazzaniga’s question of how on earth the brain enables mind. ■

Anil Ananthaswamy is a consultant for *New Scientist*

One funeral at a time...

Which scientific ideas ought to die? **Simon Ings** finds out

This Idea Must Die: Scientific theories that are blocking progress edited by John Brockman, Harper Perennial, \$15.99/£9.99



THE physicist Max Planck had a bleak view of scientific progress. “A new scientific truth does not triumph by convincing its opponents...” he

wrote, “but rather because its opponents eventually die.”

This is the assumption behind *This Idea Must Die*, the latest collection of replies to the annual question posed by impresario John Brockman on his stimulating and by now venerable online forum, Edge. The question is: which bits of science do we want to bury? Which ideas hold us back, trip us up or send us off in a futile direction?

Some ideas cited in the book are so annoying that we would be better off without them, even though they are true. Take “brain plasticity”. This was a real thing once upon a time, but the phrase spread promiscuously into so many corners of neuroscience that no one really knows what it means any more.

Other ideas, especially in the more anthropocentrically inclined sciences of economics and computer science, reflect more our natural bent for binary oppositions and good stories than they reveal real things about the world. This is where things get very interesting indeed, making Brockman’s latest book essential, as well as enjoyable, reading.

More than any amount of

pontification (and readers wouldn’t believe how many new books agonise over what “science” was, is, or could be), Brockman’s posse capture the essence of modern enquiry. They show where it falls away into confusion (the use of cause-and-effect thinking in evolution), into religiosity (virtually everything to do with consciousness) and cant (for example, measuring nuclear risks with arbitrary yardsticks).

This is a book to argue with – even to throw against the wall at times. Several answers, cogent in themselves, still hit nerves. When

“The next person to ask Julia Clarke about the first bird will probably get a cake fork in their eye”

Kurt Gray and Richard Dawkins, for instance, stick their knives into categorisation, I was left wondering whether scholastic hand-waving would really be an improvement. And Malthusian ideas about resources inevitably generate more heat than light when harnessed to the very

different agendas of Matt Ridley and Andrian Kreye.

On the other hand, there is pleasure in seeing thinkers forced to express themselves in just a few hundred words. I carry no flag for futurist Douglas Rushkoff or psychologist Susan Blackmore, but how good to be wrong-footed. Their contributions are among the strongest, with Rushkoff discussing godlessness and Blackmore on the relationship between brain and consciousness.

Every reader will have a favourite. Mine is palaeontologist Julia Clarke’s plea that people stop asking her where feathered dinosaurs leave off and birds begin. Clarke offers lucid glimpses of the complexities and ambiguities inherent in deciphering the behaviour of long-vanished animals from thin fossil data. The next person to ask about the first bird will probably get a cake fork in their eye.

This Idea Must Die is garrulous and argumentative. I expected no less: Brockman’s formula is tried and tested. Better still, it shows no sign of getting old. ■



ALAN HORTON/GETTY

View from the grave: to progress, science must bury its opponents

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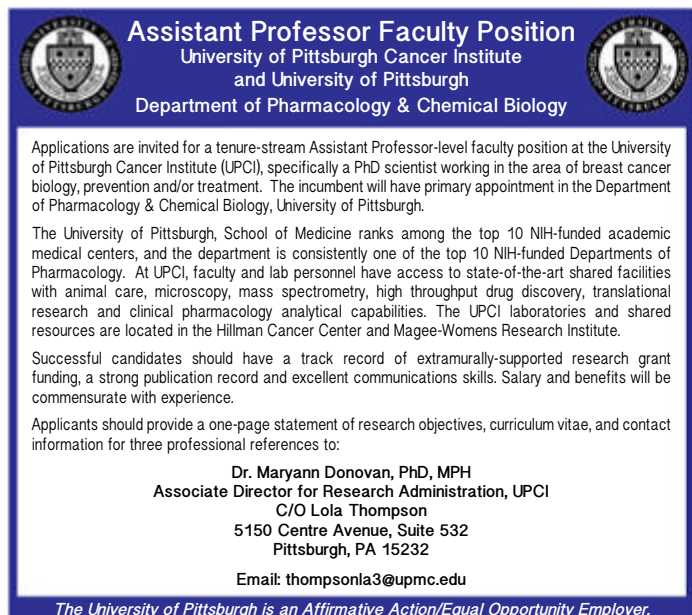
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Dr. Maryann Donovan, PhD, MPH
Associate Director for Research Administration, UPCI
C/O Lola Thompson
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Application Instructions

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Please email academicservices@bates.edu for further consideration, and don't forget to mention you saw us in New Scientist Magazine.



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The Director should possess broad scientific vision and have established a strong record of achievement and leadership, preferably in astronomy or a closely related field. The Director should also have demonstrated the skills and experience critical for administration and management, and be adept in organizational and international relations. The successful candidate will possess excellent communication and negotiation abilities. The new Director should continue to work with the community to identify potential new missions, carry out studies for them, and to partner with the community to enable such missions. Currently, the Institute is working on concepts for WFIRST/AFTA and next generation space telescopes. The new Director of STScI must be poised to lead the organization, working with our partners, the scientific community and the public through the challenges of transitioning the Institute to HST's successor mission, the James Webb Space Telescope.

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Materials and nominations should be submitted to directorsearch@aura-astronomy.org and addressed to:

Garth Illingworth, Chair
STScI Director Search Committee, c/o AURA
1212 New York Avenue NW, Suite 450
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AN ICON RETURNS

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Is anyone out there?

From Ian Simmons

John Bailey's pessimistic view that a lack of alien visitors indicates there are no aliens out there (21 February, p 54) carries with it two hidden assumptions: an advanced civilisation will aspire to interstellar travel, and they will develop the means to do so.

It may be that interstellar travel cannot be achieved on timescales that are meaningful to living organisms. Voyager I, humanity's most distant space probe, won't actually leave the influence of the sun's gravity for another 17,000 years, let alone reach another star.

Anything we are likely to build in the foreseeable future won't do more than shave a few thousand years off that, and what civilisation is going to sit around for 10,000 years awaiting an answer from a probe it's unlikely to even remember it sent?

It is now over 40 years since we even sent anyone to the moon, and a combination of economics and politics has stifled our ability to get out of Earth orbit since then, let alone reach for the stars.

Similarly, alien civilisations may be out there, but have never managed to visit us simply due to budget cuts.

Monkseaton, Tyne and Wear, UK

From Adrian Ellis

John Bailey concludes that since we haven't been bombarded with self-replicating alien space probes or spotted heat signatures in space, there probably aren't any advanced civilisations living in our galaxy.

He seems to think that advanced races will have a "more is better" philosophy, but climate change is showing us that the opposite is the only intelligent long-term strategy.

If this is correct, then the more advanced an alien race is, the less visible they will be. It's the quiet ones that are clever, not the shouters.

Hampton, Middlesex, UK

From Neil Doherty

We ought not to fear attracting advanced aliens through interstellar signals (21 February, p 8). Considering the chances of any sentient life having the technology to detect, recognise



and understand our signals, and the distances involved to travel to its source, we will be a very advanced race ourselves by the time they arrive.

Barnsley, South Yorkshire, UK

Some crap questions

From Philip Abbott

Jessica Hamzelou describes the enormous influence intestinal bacteria have on the behaviour of the human body (14 February, p 8).

I wonder if this casts doubt on the validity of epidemiological studies on the diet. Could the benefit of a Mediterranean diet be dependent on a Mediterranean faecal biota?

To my knowledge, standardisation of faecal biota isn't a feature of dietary surveys. Surely the effect of diet can only be meaningful if this factor is taken into account – especially if a faecal transplant can trigger obesity, as Hamzelou describes.

As a final thought, when one is choosing a faecal donor, it may not pay to choose someone with an active sporting lifestyle. The physical fitness might be compensating for deficiencies in the microbiome. Would it not be better to choose a healthy couch potato whose biota are

keeping them fit, despite their inactive lifestyle?

Teddington, Middlesex, UK

The fine germ line

From Jeremy Greenwood

I agree with Michael Le Page's argument for genetic alteration of embryos to treat those with major abnormalities (14 February, p 26), but where do you draw the line?

Congenital deafness? A genetic predisposition to cancer? A predisposition to stammering? I stammer, and am pleased I was not interfered with at conception.

I think that as technology improves and such interventions become routine there is the risk of laudable intentions towards perfection taking the whole thing too far. Some genetic disorders have benefits. Sickle cell disease, for example, confers a level of protection against malaria.

There will be other benefits attached to less-severe diseases that we are not aware of. We can never accurately foretell the future, so reducing our genetic diversity is not without peril. There may well be a value to nature's lottery.

So yes, let's have germ-line alterations, but these should only be for a very limited range of defined conditions, and never done without counselling and informed consent.

Bacup, Lancashire, UK

Predicting trouble

From Geoff Rowe

Hal Hodson draws our attention to the increasing prevalence of automated systems that tend to be driven by predictive equations (7 February, p 30).

These equations often have one thing in common: they rely on incomplete and proxy information to make their predictions. It is sobering to consider how accurate similar predictive equations are in fields

like medicine or epidemiology.

Although valuable insights are gained from epidemiological studies, say, the predictive equations derived from them may not be good enough to predict individual choice, behaviour or risk. This can be put down to the use of incomplete, inappropriate or inaccurate indicators.

The public should be given assurance that the predictive equations used in banking or national intelligence meet exceptionally high standards.

Ottawa, Canada

No need to frack

From Steven White

In examining whether the UK should press ahead with fracking for gas, you write that a lot of imported gas originates in Russia (14 February, p 10).

But according to government figures, the gas we import comes primarily from Norway, Qatar and the Netherlands. The prevalent misconception that we need to frack to keep the lights on, and that we get our gas from Russia, makes it hard to have a sensible debate on energy security, and whether we should risk going "all out" for shale gas in this country.

As a resident of the north of England, I'd much prefer to see investment in energy sources that start us on the path to displacing fossil fuels.

York, UK

■ The editor replies:

You are correct. We meant to say that importing more gas to the UK could increase demand for Russian gas in other countries.

Myco-coco

From Craig Sams

Colin Barras credits the leaf shape of the coco de mer tree for the high level of nitrogen and phosphorus in the soil around the

tree, as it funnels rainwater and the nutrients it picks up down the trunk, but there is another explanation (14 February, p 13).

The dense, fibrous root zone of this palm plays host to a community of mycorrhizal fungi that ferry otherwise unavailable phosphorus to the tree. The fungi also provide carbohydrate energy to the nitrogen-fixing bacteria in the soil.

Rainwashed nutrients may well play a role, but unless the researchers measured the microbial levels in the root zone the contribution of these organisms should not be ignored. *Hastings, East Sussex, UK*

■ The editor replies:

This is a very good point, and the researchers are looking into options to study the potential relationship between coco de mer and mycorrhizal fungi.

Microbial gold

From Brian King

I don't think it is disputed that there was some biological contribution to the formation of the gold deposit in the Witwatersrand basin (7 February, p 11). Since its discovery, various theories have been put forward as to how the deposit formed, including sedimentation, hydrothermal processes and precipitation by microbes.

That gold can form under anaerobic conditions is well known and by the late 1960s photomicrographs clearly showed the close association of some of these minerals with microbes, but this is relatively rare. It is generally believed that the Witwatersrand gold originated in the Archean greenstone belts to the north, south and west. The current exposures of these rocks all contain gold and most have been or are being exploited.

Much of the gold now lies in conglomerates believed to have been laid down in fluvial fans.

I understand that only in the distal parts of the fans in the Witwatersrand is there a biological association with minerals, mainly gold and uraninite.

Barton on Sea, Hampshire, UK

Cancer coaster

From Chris Good

Peter Borrows asks if roller coasters could be used to treat brain cancer (14 February, p 55). The answer is no.

The brain produces cerebrospinal fluid. Most of this fluid passes out to bathe the outer surface of the brain and spinal cord, from where it is reabsorbed. Anything blocking this flow, such as a tumour, will lead to a life-threatening increase in pressure within the brain.

A sudden change in the position or motion of the head, such as on a roller coaster, may move a tumour away from the drainage channel, unblocking it and temporarily relieving the pressure. But this is only a temporary measure and surgery is still required to remove the tumour.

Maidenhead, Berkshire, UK

No proving god

From Kate Fleming

Theists and atheists can at least agree on one important statement: "There is no such thing as god" (21 February, p 54).



For the theist, this isn't because god isn't real, but because god isn't a thing. God by definition is the author and sustainer of creation; not an item within it.

Faced with creation, a theist draws the conclusion that a creator is responsible. Trying to pin god down using the scientific method is like attempting to experience the creative powers of Beethoven through chemical analysis of the ink on his manuscripts. We can do it, but it doesn't get us very far.

London, UK

Megaflood folly

From Ayman Asfour

In his article on megaprojects, Michael Marshall discusses flooding the Qattara depression in Egypt (3 January, p 34). This is an old idea that will lead to the creation of another Dead Sea.

Evaporation will gradually increase the salinity of the water until a supersaturated salt lake is created. The salt water will seep under the desert sand and contaminate the underground freshwater reservoirs that supply the nearby oases of Siwa and Qara. Finally, the salt water will cause the groundwater level to rise and flood the oases in the desert.

Please proceed with damming the Atlantic or the Mediterranean instead.

Toronto, Canada

Dangerous dance

From Donald Wilson

I was upset by the bad press given to Scottish country dancing by Roger Malton (14 February, p 55).

This type of dancing should certainly not be high impact, nor cause any twisting if done in proper light shoes on a suitable floor. It is in fact very healthy exercise for both mind and body with a large "feel-good" factor, and very few resultant injuries.

I started Scottish country dancing nearly 60 years ago and recently held a ball to celebrate my 80th birthday. Most of the dancers were not young, but they were certainly all fit and energetic.

Coton, Cambridgeshire, UK



Baby boom and bust

From Eric Kvaalen

Health minister Beatrice Lorenzin needn't worry about Italy's falling birth rate (21 February, p 8).

If each woman has 1.39 children, it will take about 49 generations for the population to fall to 1 (at which point Italians will presumably go extinct).

There's nothing to fear from a lower population. Historically, Italy has always had a lower population than now.

Les Essarts-le-Roi, France

For the record

■ An error landed in our story on meteors (21 February, p 13): Manuel Moreno-Ibáñez is affiliated to the Institute of Space Studies (CSIC-IEEC) in Barcelona, Spain.

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35,000 DOMAINS SOLD IN THE FIRST 18 HOURS - EXPANDING ALMOST AS FAST AS THE UNIVERSE



IDLY reading a random back issue of *New Scientist* in the bathroom, we came across a letter from David Marjot reminding readers of Hickam's dictum (19 October 2013, p 30). We feel this exception to the much better known Occam's razor deserves more notice.

Hickam's dictum holds simply that "a patient can have as many diseases as they damn well please". Take, for example, someone showing up at a clinic with a headache, fever, runny nose and excruciating pain in a big toe. Occam's razor - often given as "do not multiply entities unnecessarily" - suggests a diagnosis of improbabilis, a single entity that covers all the symptoms but is spread only by river worms in the land of Nonexistentia.

On the other hand, the unfortunate could have flu on top of gout.

OCCAM'S razor is notable these days for people using and abusing it to justify their non-standard mentation - particularly about conspiracy theories. It can also be applied to debunking these: perhaps introducing a remote-controlled holographic missile-equipped passenger plane does

not help to understand events at the Pentagon in Washington DC on 11 September 2001?

Its modifier, Hickam's dictum, described above, has similar utility. A tragedy may have more than one contributing cause: perhaps the Pont de l'Alma road tunnel in Paris, France, was crowded, and the driver of the car bearing Diana Windsor not sober?

Indeed, it remains to be seen which may need to be wielded in response to the flood of paranoid postings we sadly predict will follow our report on new laser weapons that induce temporary blindness (page 44).

THERE is little new under the sun. While surveying the rather sparse references to Hickam's dictum, we encountered Walter Chatton, a 14th-century contemporary of William of Occam (or Ockham) who argued philosophy with him. So far, we understand that Chatton proposed a set of principles for when it makes sense to introduce a "new entity" to your theory, contrary to Occam's razor. We hope, one day, to emerge from our

present pit of late-medieval philosophical discourse bearing a gem of crystalline clarity.

DETECTING fake journals is another area in which the competing principles of Occam and Hickam may be in tension, constructively. It's increasingly difficult to tell the "hopeful monsters" - that is, publications hoping to have evolved new business models that make everything in the academic publishing garden rosy - from the scams.

Joan Curzio seeks our help evaluating arcjournals.org - and we're stumped. The soliciting letter is arguably in perfectly good Indian English. The lack of named editors-in-chief for the medical journals due to launch on 10 April may be a website flaw. The papers referencing Ayurvedic principles are beyond us.

MEANWHILE an organisation called ACI InSights sends Feedback an invitation to "Revolutionize your Research with the world's only repository of published scholarly blog content". Hypothesis: the content may not be fully state-of-the-art. Experiment: list the contributions relating to climate change. Result: a whole series of blog postings by Judith Curry, whose perspective could be described as non-standard, such as "Climate psychology's consensus bias". Need to introduce new entities to our hypothesis: none, yet.

CLEARER cases are those of *Computational Intelligence and Electronic Systems* and the *Aperito Journal of NanoScience Technology*. The headline of a news article about the two, sent by Philip Clapham, tells most of the story: "When Maggie Simpson can get a paper into a science journal, you know you've got trouble."

Alex Smolyanitsky, a Colorado-based materials scientist, followed up Feedback's intermittent running story (most recently 28 June 2014) on the SCIGen program, which generates utter

nonsense vaguely in the form of a computer science paper. He submitted a pseudopaper to both journals, pseudonymously.

PONDERING Hickam's dictum, Feedback wonders about a roughly equivalent principle in risk analysis. It has long seemed to us that anyone who suspects the probability of a set of independent failures occurring together to be vanishingly small should urgently make plans to cope with them all happening at once.

Nuclear accidents provide examples - but not, as far as we can tell, a name. Can you help?

FINALLY, it is time to excavate from our piling system a response to our query about whether readers were celebrating Pi Approximation Day on the (UK format) date 22/7 (12 July 2014). "I imagine," Andrew Green writes, "that there is great excitement in the Pi community about



celebrating at 9:26 and 54 seconds on the [US format] date 3/14/15, although the celebrations may be somewhat transitory".

Of course 3/14/15 9:26:54 is the closest we'll get to the precise value of the constant that relates the circumference of a circle to its diameter for, ooh, ages. So: how will you toast pi next week?

You can send stories to Feedback by email at feedback@newscientist.com. Please include your home address. This week's and past Feedbacks can be seen on our website.

Reader Paul Smith suggests "selling homeopathic preparations of rhino horn and sending all profits to rhino conservation". Nice subversion of fruitloper. First, a discussion of ethics...

Mind lags body

I'm 77 and, like many people my age, tend to stoop rather than stand up straight. A few months ago I was standing by the kitchen door, talking idly. For some reason I turned and hit my head a stunning blow on the door frame. More recently I was looking over my wife's shoulder as she worked on her computer; I reached out my hand, pointing to something on the screen. As I pulled my hand back, my fingers got caught in a box on the table and I toppled it over on to the floor, spilling its contents. After a while I realised that both times I'd been stooping. In my mind's eye my head was clear of the door frame and my hand well above the table, but my stoop cancelled both. Is our body image slow to adjust to reality? If so why, and can it be fixed?

■ The subconscious perception of your body orientation and movement is called proprioception. This aspect of awareness is supplied by the vestibular system in the inner ear and by nerves in the muscles and joints. It lets you know where your hands and feet are when you are blindfolded.

Proprioception is learned through experience, but can be compromised by changes in body structure due to injury, ageing or adolescence. Teenagers who go through a growth spurt may, when playing sports, start to drop balls that they used to catch; their arms are now longer than their brain remembers. The adolescents' proprioception lags

behind their growing bodies. However, neuromuscular pathways can be retrained with specific practice: evidence shows that juggling helps cricketers.

The correspondent's proprioceptive experience is based on more than 70 years of standing tall. This conflicts with his current stoop and results in accidents. The good news is that movement and awareness exercise such as t'ai chi or yoga not only improves proprioception, but diminishes the likelihood of the falls and broken bones that are the bane of older people.

*David Muir
Edinburgh, UK*

Tree time

It is generally accepted that the increase in day length in the spring is what prompts deciduous trees to begin growing their leaves. But how does a tree know that the days are getting longer?

■ Everyone knows that plants need light to grow, and that most plants grow in different ways at different times of the year, particularly in temperate latitudes. This effect, called photoperiodism, enables temperate plants to control when they grow new leaves and when to drop them in the autumn.

However, it isn't the length of the day which is important, but the uninterrupted dark period – the length of night. During the period of darkness the plant

produces a photosensitive protein called phytochrome, the concentration of which controls the onset of dormancy in autumn and bud burst in spring.

Even a small amount of electric light during the hours of darkness can upset this, and it is noticeable when a tree encroaches on a street light. In autumn, when the tree is starting to become dormant, the leaves closest to the light are often the last to fall. However, trees and plants are unaffected by light from the moon.

*John Crofts
Sherwood, Nottinghamshire, UK*

■ Back in 1920, botanists Wightman Wells Garner and Harry Ardell Allard thought the length of daylight was the key to photoperiodism. So by the time it was discovered that the hours of unbroken darkness were responsible, plants had already been labelled as "long-day", "short-day" or "day-neutral".

Chrysanthemums are short-day



plants and will only flower if there are enough hours of darkness. Growers of these plants used to keep their greenhouse lights on all night to delay flowering, until it was discovered that just a brief burst of light would suffice.

This is down to the photosensitive phytochrome pigment. It exists in two states and when exposed to sunlight, the amount of pigment in either state is about the same. As night falls more of the pigment switches to the active state. But a flash of light will redress the balance and this is enough to postpone flowering in short-day plants or induce it in long-day plants.

Even seeds are armed with this pigment, which allows them to use the direction of sunlight to sense which way is up (this ensures shoots and roots head off in the right direction). They can "calculate" how deeply they are buried from the light intensity and can even detect the presence of overhanging foliage and postpone germination.

*Mike Follows
Sutton Coldfield, West Midlands, UK*

This week's question

ANGLE OF DANGLE

What are these (see photo)? There were about 20 creatures, some headless. They were found in Victoria state, Australia, about 10 kilometres from the coast at Ceduna.

*Chris Jaminon
Atherton, Queensland, Australia*

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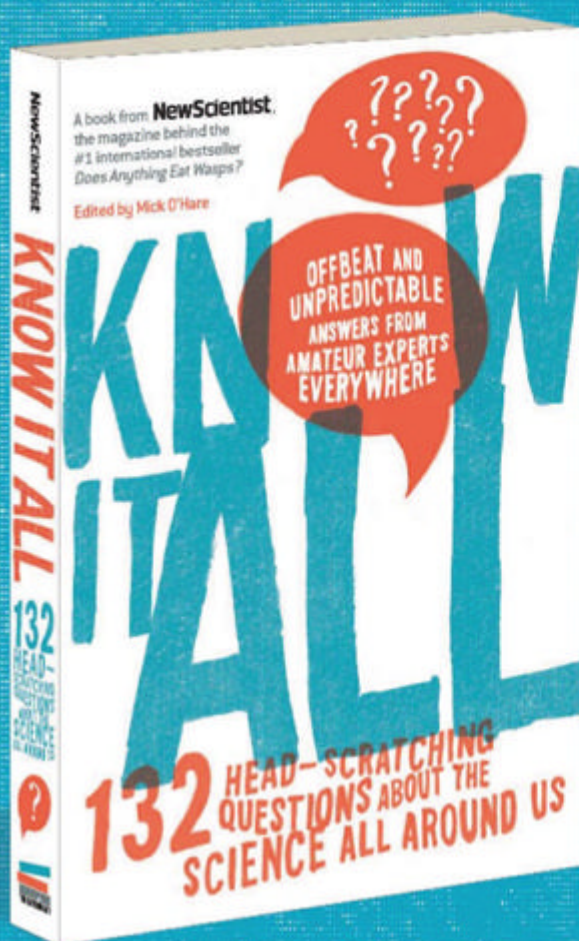
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